BULLETIN

Of The

Southwestern Association
Of
Petroleum Geologists

Volume 1

Chas. H. Taylor, Editor

Published By The Association

1917

CONTENTS

Page

Officers for 1917 5
Historical Sketch of the Organization 6
Constitution and By-Laws 7
Members of the Association 10
Proceedings of the Second Annual Meeting 11

PAPERS AND DISCUSSIONS

Page

Geological Work in the Southwest. By Charles N. Gould 20
Coastal Salt Domes. By William Kennedy. (with discussion) 34
The Humble Oil Field, Texas. By Alexander Deussen. (with discussion) 60
Salt Domes of Northwestern Europe. By W. A. I. M. von Waterschoot van der Gracht 85
Notes on the Texas Permian. By W. E. Wrather 93
The Vertical Component in Local Folding. By James H. Gardner. (with discussion) 107
The Granites of Kansas. By Charles H. Taylor. (with discussion) 111
Hints to Prospective Geologists. By J. A. Udden 127
An Outline for a Type Report on An Oil Field. By W. C. Kite 131
North-South Correlation of the Pennsylvanian of Oklahoma. By Edward Bloesch 134
Observations on Post-Permian Deposits in North Central Oklahoma. By Edward Bloesch 134
Some Effects of Capillarity on Oil Accumulation. By A. W. McCoy 140
Significant Features of Western Coal Deposits. By Charles T. Kirk 148
Oil and Gas Possibilities in Mississippi. By A. F. Crider 152
Oil Development in Colombia, South America. By K. D. White 156

OFFICERS FOR 1917

J. ELMER THOMAS, *President*
313 Daniels Bldg., Tulsa, Okla.

ALEXANDER DEUSSEN, *Vice President*
405 Stewart Bldg., Houston, Texas

MAURICE G. MEHL, *Secretary-Treasurer*
University of Oklahoma, Norman, Okla.

CHARLES H. TAYLOR, *Editor*
315 W. 17th St., Oklahoma City, Okla.

HISTORICAL SKETCH OF THE ORGANIZATION*

So far as the writer can learn, the idea of organizing the geologists of the Southwest for the purpose of meeting to discuss problems of mutual interest, originated in a conversation between Mr. Charles H. Taylor and Mr. E. L. DeGolyer early in 1915.

In the fall of the same year Mr. Taylor, then head of the Department of Geology in the University of Oklahoma, began planning a convention of the geologists of the Southwest. He recognized the fact that many of the men could not avail themselves of the benefits of the existing geological societies because they, as a rule, held their meetings in the East. He determined to establish an exchange for geological thought nearer the center of the activities of Oklahoma and the nearby states.

At about this time Mr. J. Elmer Thomas sent invitations to a dinner at Tulsa, apparently with something of the same thing in mind as that upon which Mr. Taylor was working. At this dinner attended by some forty geologists, Mr. Taylor was given an opportunity to present the matter of organization.

Some time later personal and circular letters were sent to all of the geologists of the Southwest, in so far as names were available, urging them to be present at a convention called for January 7-8, 1916, at Norman, Oklahoma. This first meeting of the future Southwestern Association was attended by about fifty geologists, exclusive of those at Norman. Papers dealing with many phases of the geology of the Southwest were read and discussed with much interest. It was decided to make this meeting the first of a series, but little at this time was done to perfect an organization.

Before the close of the meeting it was tentatively decided to hold the next meeting at Tulsa and a committee composed of Mr. Taylor as chairman, Mr. C. W. Shannon, Mr. F. R. Reese and, later Mr. W. E. Wrather, was given charge of the affairs of the next meeting of the geologists of the Southwest. It is to this committee that much of the credit is due for the successful meetings at Tulsa, February 9-10, 1917, and the final perfection of the organization, as set forth in The Proceedings of the Association for that year.

---

*Prepared by M. G. Mehl in accordance with the request of the executive council.

THE CONSTITUTION

Article I.—NAME

This association shall be called THE SOUTHWESTERN ASSOCIATION OF PETROLEUM GEOLOGISTS.

Article II.—OBJECT

The object of this association shall be the promotion of the science of geology among the men engaged primarily in the geology of petroleum and gas in the several states commonly spoken of as THE SOUTHWESTERN STATES.

Article III.—MEMBERS

Section 1.—Any man actively engaged in the work of the petroleum geologist, studying petroleum geology, teaching this subject or related subjects, or connected with a state geological survey in the capacity of geologist or assistant geologist, in any of the states usually referred to collectively as THE SOUTHWESTERN STATES, is eligible to active membership in the SOUTHWESTERN ASSOCIATION OF PETROLEUM GEOLOGISTS, providing,

That he is a graduate of an institution of collegiate or university standing in which institution or institutions he has done his major work in geology, or

If he shall have carried on studies in such institution or institutions and shall have published a creditable book on some phase of geology or an article on some geological subject in some periodical of generally accepted scientific standing.

Section 2.—Any man having completed as much as twenty hours of geology (an hour shall here be interpreted as meaning as much as sixteen recitation or lecture periods of one hour each, or the equivalent in laboratory) in a reputable institution of collegiate or university standing, shall be eligible to associate membership in THE SOUTHWESTERN ASSOCIATION OF PETROLEUM GEOLOGISTS, providing that at the time of his application for membership he shall be engaged

in geological studies in an institution of collegiate or university standing or shall be engaged in geological work in any of the several states usually referred to collectively as THE SOUTHWESTERN STATES.

Section 3.—Active and associate members shall be elected to the association according to the qualifications outlined in sections one and two, providing that the applicant properly fills out the regular application blank, including the signatures of two active members of the association, and that such application be approved by at least three of the members of the executive committee of the association as provided for in Article IV, section 1 and 4.

Section 4.—Associate members shall enjoy all the privileges offered by the association save that the associate members may not hold any office, sign the application for new members, nor vote on constitutional amendments.

Article IV.—OFFICERS

Section 1.—The officers of the association shall consist of a president, a vice-president, a secretary-treasurer, and an editor-in-chief, who together shall constitute the executive committee of the association.

Section 2.—The officers shall be elected annually from the association at large.

Section 3.—No man shall hold the office of president or vice-president for more than two years in succession.

Section 4.—The executive committee shall consider all nominations for membership and pass on the qualifications of the applicant, shall have the control of the association's work and property, shall determine the manner of publication and pass on all materials presented for publication, and may call special meetings when and where thought advisable and arrange for the affairs of the same.

Article V.—MEETINGS

The annual meeting shall be held at a time most convenient for the majority of the members at a place designated by the executive committee. At this meeting the election of members shall be announced, the proceedings of the preceding meeting

be read, all society business transacted, scientific papers read and discussed, and officers for the ensuing year shall be elected.

Article VI.—AMENDMENTS

The constitution may be amended at any annual meeting of the association by a vote of three-fourths of the total active membership, providing that the proposed amendment is signed by five or more active members and that it shall have been called to the attention of the entire active membership at least one month before the time of voting on the amendment.

Article VII.—PUBLICATION

The proceedings of the Annual Meeting and the papers read shall be published in an annual bulletin. This shall be under the immediate supervision of the Editor-in-Chief, assisted by a Publication Committee, consisting of the Editor-in-Chief and three other members to be appointed by the President.

BY-LAWS

DUES.—The regular dues of an active member of the association shall be five dollars. The yearly dues of an associate member of the association shall be three dollars. These annual dues are to be paid to the secretary-treasurer on or about January first for the year ending the following December.

Any member in arrears for more than two years shall be dropped from the roll of members providing he shall have been informed of his deficiency by the secretary-treasurer, a second time after an interval of six months.

The payment of the yearly dues entitles the member to receive without further charge, one copy of the proceedings of the association for that year.

AMENDMENTS

These by-laws may be amended by the vote of three-fourths of the active members at any annual meeting.

ACTIVE MEMBERS *OF THE* SOUTHWESTERN ASSOCIATION MAY 19, 1917

Allen, E. G.
Aurin, Fritz
Baker, R. F.
Bartram, John G.
Bauer, C. Max
Bloesch, Dr. Ed
Boyd, H. E.
Brown, R. W.
Burton, Geo.
Burress, Geo. H.
Calvert, W. R.
Conkling, R. A.
Cragoe, Prof. E. J.
Cumming, C. L.
Cutler, Willard W.
Dawson, L. R.
Decker, Prof. Chas. E.
DeGolyer, E. L.
Deussen, Alexander
Donnely, L. G.
Drake, Dr. N. F.
Easton, H. D.
Eckes, Chas. E.
Fath, A. E.
Fischer, Dr. A.
Fohs, F. Julius
Foster, Wm. H.
Gardner, Jas. H.
Garrett, D. Loy
Gould, Dr. C. N.
Green, F. C.
Grube, Wesley F.
Hammill, Chester A.
Honess, Chas. W.
Hartley, Burton
Haworth, Huntsman
Haworth, Dr. Erasmus
Haynes, W. P.
Hazeltine, Roy S.
Heald, K. C.
Herald, J. M.
Hinds, Earter P.
Hook, J. S.
Howell, J. V.
Hutchison, L. L.
Irwin, Joseph Stewart
Jackson, Thomas F.
Kennedy, Wm.
Kirk, Dr. Charles T.
Kite, W. C.
Lee, Marvin
Loomis, Harve
McCoy, Alex. W.
McCullough, A. A.
McKee, H. Harper
Mehl, Dr. Maurice G.
Meyer, Geo. H.
Millard, Wm. J.
Monnett, Prof. E. V.
Moore, Dr. R. C.
Newby, Jerry
Parker, Everett C.
Pemberton, J. R.
Perrine, Dr. Irving
Porter, C. L.
Powers, Sidney
Price, S. S.
Prout, F. S.
Pynch, Prof. I. A.
Riggs, R. J.
Sands, J. M.
Scudder, E. W.
Severy, C. L.
Shannon, C. W.
Small, Walt M.
Springfield, Carl K.
Stacy, Dean M.
Taylor, Prof. Chas. H.
Thomas, J. Elmer
Udden, Dr. J. A.
Waite, V. V.
Von Waterschoot, Van der Gracht, W. A. I. M.
Williams, Prof. A. J.
Willis, S. M.
Wrather, W. E.
Woodruff, E. G.
Wright, H. F.

ASSOCIATE MEMBERS OF ASSOCIATION

Berger, Walter R.
Davis, E. H.
Grove, Ivan H.
Hinds, J. H.
MacKay, Hugh
Mulky, Francis P.
Witteveen, G. W.

Proceedings *of the* Second Annual Meeting

of the

Southwestern Association *of* Petroleum Geologists

TULSA MEETING

February 9-10, 1917.

Maurice G. Mehl, Secretary-Treasurer.

The second annual meeting of THE SOUTHWESTERN ASSOCIATION OF PETROLEUM GEOLOGISTS was called to order in a business session in the club room of the Tulsa Hotel, Tulsa, Oklahoma, Friday, 10 A. M., February 9th, 1917, Charles H. Taylor presiding.

After the address of welcome by the chairman, the matter of closer organization was opened for discussion. After some consideration of the nature of the organization desired by those present, the following motion by Mr. C. W. Shannon, was made and carried unanimously:

"That the chair shall appoint a committee of five—to include the chairman of the assembly ex-officio—to be distributed as follows:

One representative from the State University of Oklahoma, one from the State Geological Survey of Oklahoma, one from among the geologists of Tulsa, and at least one from another state.

That it shall be the duty of this committee to take charge of the business connected with the present meeting, make nominations for officers, suggest plans for the publication of the proceedings of the meeting, and arrange for future meetings."

The following were appointed to act on the committee named in the above motion:

Mr. Fritz Aurin of the State Geological Survey of Oklahoma, chairman, Mr. V. E. Monnett of the State University of Oklahoma, James H. Gardner for the Tulsa geologists, Dr. Raymond C. Moore, State Geologist of Kansas, and Mr. W. E. Wrather of Texas.

The committee was instructed to make a list of all men present at the meetings and were asked to hold a committee meeting and report to the assembly at as early a time as possible.

Mr. James H. Gardner suggested the desirability of an affiliation of the petroleum geologists with the American Institute of Mining Engineers and made the following motion which was carried:

"That the assembly express to the committee on recommendations the desirability of considering an affiliation with the American Institute of Mining Engineers."

After a lengthy discussion bearing on the publication of the proceedings of the meetings of the association, the desirability, ways and means, the election of an editor-in-chief, etc., carried on by Fohs, Drake, Shannon, Thomas, Powers, Wrather, Hager, Moore, Cox, Bryan, Perrine, Aurin, Bates, Woodruff, Mehl, Gardner, Buchler, and others, the meeting was adjourned to convene at the Tulsa Chamber of Commerce at 1:30 P. M.

SESSION AT TULSA CHAMBER OF COMMERCE

Friday 1:30 P. M., February 9, 1917.

MR. C. W. SHANNON *Presiding.*

PRESENTATION OF PAPERS

THE GRANITES OF KANSAS.
CHAS. H. TAYLOR.

Presented without manuscript or notes.

THE BEARING OF THE KANSAS GRANITES ON CERTAIN THEORIES TO ACCOUNT FOR THE SHAPING OF THE PRIMATIVE EARTH.
DR. MAURICE G. MEHL.

Presented without manuscript or notes, illustrated by diagrams. The two papers on the Kansas granites discussed by Mr. Loomis, Mr. Thomas, Mr. Conkling, Mr. Wrather, and Dr. Moore.

THE ORIGIN AND NATURE OF FOLDING.
JAMES H. GARDNER.

Read from manuscript. Discussed by Mr. Thomas, Mr. McCoy, Mr. Decker, and Dr. Bloesch.

THE APPLICATION OF GEOLOGY TO INTENSIVE DEVELOPMENT.
DORSEY HAGER.

Presented without manuscript or notes. Discussed by Mr. Woodruff.

THE POST-PERMIAN DEPOSITS OF NORTH CENTRAL OKLAHOMA
DR. E. BLOESCH.

Read from manuscript; illustrated by specimens.

THE CONTACT LINE BETWEEN THE CRETACEOUS AND THE OLDER ROCKS TO THE NORTH IN SOUTHERN OKLAHOMA

C. W. HONESS.

Presented from notes, illustrated by maps. Discussed by Mr. Calvert, Mr. Shannon, Mr. Gardner, and Mr. Powers.

THE AGE OF THE OIL IN SOUTHERN OKLAHOMA

SIDNEY POWERS.

Presented without manuscript or notes. Discussed by Dr. Perrine, Mr. Fohs, Mr. Hutchison, Dr. Mehl, and Mr. Woodruff.

An invitation was extended to the assembly to visit the Cosden Refinery the following afternoon. On a motion by Dr. Mehl a vote of thanks was tendered and the invitation accepted.

The meeting was adjourned at 5:00 P. M., to convene at 8:00 P. M. in the same room to continue the reading and discussion of papers.

NIGHT SESSION—TULSA CHAMBER OF COMMERCE

Friday 8:00 P. M., February 9, 1917.

MR. W. E. WRATHER *Presiding.*

The subject for discussion at this meeting was introduced by the chairman as follows:

The subject for discussion tonight deals with one of the most interesting phases of geology in the whole Southwest, perhaps one of the most baffling subjects that the commercial geologist in the oil business has to deal with. It is interesting both from the scientific and the commercial standpoint. It deals with the Coastal Salt Domes.

We are fortunate to secure men as well posted on this subject as Mr. Deussen and Mr. Kennedy. When I went to the coast Mr. Kennedy was there and was then an old hand at Texas geology. He has been studying these problems in Texas since 1885 and has been constantly and continuously on the ground ever since. He has access to more data, perhaps, than any other who might speak on the subject.

THE COASTAL SALT DOMES

WM. KENNEDY.

Read from manuscript.

THE HUMBLE, TEXAS, OIL FIELD

ALEXANDER DEUSSEN.

Read from manuscript. Discussed in connection with the paper by Mr. Kennedy, by Mr. Millard, Mr. Woodruff, Mr. Powers, Mr. Hartley, Mr. Hutchison, Mr. Thomas, Dr. Moore, and others.

The meeting was adjourned to convene at Kendall College at 10:00 A. M., February 10th.

MORNING SESSION—KENDALL COLLEGE

Saturday, 10:00 A. M., February 10, 1917.

MR. WRATHER *Presiding*

THE CORRELATION OF THE OIL SANDS OF OKLAHOMA

FRITZ AURIN.

Presented without manuscript, illustrated by maps and charts.

THE REPORT OF THE COMMITTEE ON RECOMMENDATIONS

Presented by FRITZ AURIN

Mr. Chairman:

We, your committee on recommendations, beg to report as follows:

1.—That this organization be perfected and known as THE SOUTHWESTERN ASSOCIATION OF PETROLEUM GEOLOGISTS.

2.—That the officers shall consist of a President, Vice-President, and a Secretary-Treasurer, and suggest the following names for these offices in order:

J. Elmer Thomas, Alexander Deussen, and Maurice G. Mehl.

These suggestions were put into the form of motions and voted on in order. Both carried. The newly elected president, J. Elmer Thomas, took the chair.

The meeting was adjourned for luncheon served by the members of the department of Domestic Science of Kendall College.

AFTERNOON SESSION, FEBRUARY 10, 1917

Kendall College, 1:30 P. M.

MR. J. ELMER THOMAS *Presiding.*

The report of the recommendation committee continued.

It is further recommended:

1.—That the ASSOCIATION publish the papers presented at the meeting of the year before at Norman, Oklahoma.

2.—That the office of Editor-in-Chief be created.

3.—That a committee be appointed by the chair to draft a constitution and by-laws.

4.—That the chair appoint a committee on publication.

These suggestions were taken up in order in the form of motions and carried.

By sealed ballot Charles H. Taylor was elected Editor-in-Chief.

The chair appointed a committee to draft a constitution and by-laws as follows:

Mr. Wrather, chairman, Mr. Valerius, Mr. Newby, Mr. Woodruff, Mr. Hazeltine, and Mr. Severy.

The chair appointed a committee on publication as follows:

Mr. Taylor, chairman, Mr. Shannon, Mr. Hutchison, and Mr. Gardner.

Mr. Hutchison moved

"That the committee on constitution and by-laws be instructed to permit any man to become a member of the association providing he is a graduate of a college or university of standing or has published an article in a scientific journal of standing. That students of geology in their senior year be permitted to become associate members."

This motion was supplanted by one to the effect that the committee be authorized to draw up the constitution as they should see fit and let the roll of attendance of the present meetings constitute the membership of the Association with standing according to the requirements set forth in the constitution to be adopted at a later date. This motion was carried.

PIONEERING IN GEOLOGY

L. L. Hutchison.

Presented without manuscript or notes.

The regular session was here dismissed for the visit to the Cosden Refinery. The meeting was then continued in an informal manner in order that those not interested in the trip might hear the unread papers.

SIGNIFICANT FEATURES OF WESTERN COAL DEPOSITS

Chas. T. Kirk.

Presented from Manuscript.

OIL POSSIBILITIES IN ARKANSAS

Mr. N. F. Drake.

Presented from notes, illustrated by charts and maps.

COLOMBIA, SOUTH AMERICA

K. D. White.

Read from manuscript.

After a resolution was passed thanking Professor Gragoe for tht courtesies extended, the meeting was adjourned.

PAPERS AND DISCUSSIONS

GEOLOGICAL WORK IN THE SOUTHWEST

By CHARLES N. GOULD, *Oklahoma City, Oklahoma*

(Norman meeting, January, 1916.)

Generally speaking, geological work in the United States may be classified under one of four heads, namely, work done by the authority of the Federal government, that is to say, by the United States Geological Survey; work done under the authority of state governments, usually by state geological surveys; work done by private individuals, usually teachers of geology in institutions of learning; and lastly, work done by corporations.

Geological work may again be classified as either purely scientific, purely economic, or a combination of the two. For instance, reports on paleontology or on stratigraphy are scientific. A mine report, or a report on an oil field is apt to be purely economic. Work done by the Federal Survey and by the state surveys is likely to take on both scientific and economic character, for the men at the head of these bureaus, soon learn, and often to their sorrow, that the public in general has no use for purely scientific information, and unless economic results are not only promised, but actually delivered, there is no public money for the carrying on of geologic surveys. It is for this reason that a state survey in order to exist, must constantly pour out a flood of so-called economic bulletins, adorned on the front page with the magic name of some supposedly valuable mineral.

Work done by private individuals, men who are geologists for the love of the work, is more likely to be purely scientific, but these men are often compelled to hunt for a medium of publication. Work done by corporations is almost sure to be economic. A corporation is said to have no soul; neither has it any scientific instinct, except in so far as science may be used as a medium to breed dollars.

In the discussion of the geological work of the Southwest all four classes of work mentioned above must be recognized. The Federal government has done its share of investigation

in this part of the United States, and has published valuable results. Every state in this section of the country has carried on geological surveys. Scores, not to say hundreds, of private individuals in the various universities and colleges, often without encouragement or hope of remuneration, have pursued investigaions of far-reaching results. At different times various corporations have employed geologists, chemists and engineers to examine and report upon the various mineral products of the great Southwest.

There is no means of knowing the number of different individuals who have labored in this section of the country. Much of the work, particularly that done on oil, coal, etc., has been of such character that the results have never been published. Many geologists never publish at all, and the result of their work is lost to posterity. One of the truest things I ever learned in the course of my scientific studies was a statement made by my old friend Dr. S. W. Williston, then of Kansas, now of Chicago, one of the greatest men that American science has ever produced. Dr. Williston was the first real live geologist that I ever saw. He said, "It is the scientific damnation of any young man, who works for as much as two years in any field of scientific research without publishing." My observation of something like 20 years has taught me that this is true. For unless he publish, there is no way given under heaven or among men, by which the scientist who makes a discovery worth while, may add to the sum total of human knowledge. Unless he publish, there is no way in which he can come in contact with other minds of like character to his own, and make himself known to the scientific world. He may become wealthy, but he certainly will not become a scientist. The world does not know nor care whether or not we geologists are alive. It is up to us to take the world by the throat and make it recognize us.

There is, then, no way of knowing how many geologists have worked in the Southwest. One of the latest bulletins published by the youngest survey in the region, namely bulletin 25 of the Oklahoma Geologist Survey, entitled "A Bibliography of Oklahoma Geology," lists 639 separate articles written by 235 men, or an average of 2.7 articles per man. It is safe to say that this does not represent half of the men who first and

last have worked in Oklahoma. Many men have conducted investigations, some of them of real value, which have never appeared in type. On the other hand, the names of many men appear in that bulletin who worked chiefly in the surrounding states of Kansas, Missouri or Texas, and who perhaps did not work at all in Oklahoma. It will however, be safe to say that at least 300 men have at some time done geological work in this state. Counting then an average of 300 men for each state it will be seen that at least 1500 men have at some time done geologic work in the five states embraced in this article, namely, Kansas, Missouri, Arkansas, Oklahoma and Texas.

This southwestern country is unfortunate in one regard. It is for the most part out of the great lines of transcontinental travel which were established in the early part of the last century and which are still used by people in passing to the western coast. Geology in America had its birth in New England and the North Atlantic states, and many of the older geologists never came west in all their lives. The fathers, such men as Dana, Ashburner, Cook, Emmons, Leidy, Hall, Rogers, Hitchcock, Vanuxem, Lesley, Marsh, Newberry, Orton and others, lived, wrought, published, died and were gathered unto their fathers, supremely ignorant, most of them, of the geology of the great Southwest. Only a few, as Powell, Hayden, King, Marcou, Cope and Owen, visited this region. Even among the 20 or 30 men of the second generation of American geologists, men who today stand out preeminently as leaders of the science, men who are now in the late middle life, only one, Branner, who was at one time State Geologist of Arkansas, has been intimately connected with the geology of the Southwest. Most of the great men of science now living in America, such men as I. C. White, Van Hise, Chamberlin, Willis, Walcott, Salisbury, Kemp, Davis, W. B. Clark, J. M. Clark, Schuchert, Leith, or Campbell, really know very little at first hand of the region. Their work as a general thing, has not brought them into this part of the country, and any investigations which they may have made in this region have been hurried and incomplete.

The geologic work of the Southwest has been done largely by local men, usually by men who were either born in this region, or who came here from the eastern states as pioneers. The great geologists of the Southwest, men who have been

instrumental in shaping the development of the science of the region, are men who have lived, labored and published in this country. Men like Mudge, Hay, Swallow, Haworth and Williston of Kansas; Purdue and Drake of Arkansas; Broadhead, Winslow, Keyes, and Buckley in Missouri; Shumard, Hill, Dumble and Phillips in Texas, and Taff in Oklahoma, are for the most part, men who were either native to the state in which they worked, who came to the state as pioneers in early life, or who came west soon after graduation as instructors in some institution.

It will be obviously impossible in this paper to attempt to discuss in anything like critical details the geological work of the Southwest. One might labor for months and prepare an article which could not be read in days. All, then, that I can hope to do is to attempt to touch high places, to point out a few of the most salient facts connected with the geology of the various states in this section of the country.

One of the favorite amusements of state legislatures is the establishment of geological surveys. Another amusement is to fail to appropriate money for their maintenance. Surveys are, like springs, sometimes permanent, sometimes intermittent. The mode of control of different state surveys is as various as the surveys themselves. In some cases there is a commission appointed by the governor. Sometimes the survey is a separate political entity, and the state geologist is a law unto himself. In many cases the survey is intimately connected with, and an integral part of, the state university and the funds for its maintenance are appropriated at the same time as other university funds. In many instances the head professor of geology at the University is also state geologist. In the words of the classicist, this arrangement is "very nice for Mary Ann, but powerful hard on Abraham." Any man who is sufficiently gifted to be able to spread himself over the various details of administration, instruction, and investigation connected with running both a state survey and a department of a university, without either becoming thin in spots, or becoming frayed around the edges, is a most remarkable man. Yet there are those who have done it. Witness: Smith of Alabama, Calvin of Iowa, Haworth of Kansas, Barbour of Nebraska, Clark of Maryland, Purdue of Arkansas. In one state the state

geologist is elected at the same time as the rest of the politicians, and the results are usually commensurate with the method.

In the following paragraphs, I shall endeavor to outline very briefly the history of the various surveys of the five states discussed, including the present organization of the survey and some mention of the work done in each state.

Missouri.

The first geological survey to be organized in the Southwest was that of the state of Missouri. This survey was in operation from 1853, the date of its organization, until 1861, when it was discontinued on account of the war. During this time C. G. Swallow served as geologist. Mr. Swallow's work extended over practically all parts of the state and several reports were issued, dealing with various geological problems.

The second geological survey of Missouri was organized in 1870, and discontinued in 1876. During this time five men served as state geologist, namely, Albert D. Hager, J. G. Norwood, Raphael Pumpelly, G. C. Broadhead, and Chas. R. Williams. It will be readily understood that no permanent results could be obtained under such conditions. The work of Prof. Broadhead, for many years head of the department of geology at the state university, was of considerable value.

The third Missouri survey was organized in 1889, and is still in operation. It is under the control of a board of managers, appointed by the governor, for a term of four years. Six men have served as state geologist under this survey, namely, Arthur Winslow, 1889-1894, C. R. Keyes, 1894-1897, John Gallager and his son, Leo Gallager, 1897-1901, E. R. Buckley, 1901-1908, and H. A. Buehler, 1908 until the present time. The work of the present survey has for the most part been of a high order. Arthur Winslow the first geologist under the present regime, was an eminent scientist and a broad minded man. He planned wisely, and executed his plans. Nine reports were issued under his administration; and ten reports issued by the Keyes administration, were composed largely of material collected by Winslow and his associates. The Gallagers, father and son, issued four reports.

Dr. E. R. Buckley for seven years state geologist of Missouri, was one of the most forceful, and energetic men in the

Southwest. Both as an executive and investigator, his work was of a high order. Eight reports were issued by him and material collected for several others. He resigned his position to engage in private work and died of pneumonia in Chicago in 1911. The present state geologist of Missouri is Mr. H. A. Buehler, who came to the Missouri survey from Wisconsin as chemist. The administration of Mr. Buehler has been very successful, and five reports have been issued dealing largely with its greatest mineral resources, lead and zinc. In addition to the work of the survey, the United States Government has conducted a considerable amount of investigation in this state, chiefly under the direction of such men as Van Hise, Adams, and Siebenthal.

Kansas.

The first geological survey of Kansas was authorized by act of the legislature in 1864, and B. F. Mudge was appointed geologist. Mr. Mudge has been called the father of Kansas geology. His work was that of a pioneer, but it was largely due to his energy and enthusiasm that the early investigation in Kansas was accomplished. He was assisted by Major Frederick Haun, and C. G. Swallow. After resigning his position as state geologist, he served as professor of natural history in the Kansas Agricultural College until 1873 and died in Manhattan, Kansas, in 1879.

The second geological survey of Kansas was organized in 1865 and C. G. Swallow was made state geologist. One report was issued. Swallow's name in connection with Kansas geology will be remembered chiefly on account of his section of the Kansas Carboniferous. He was one of the first men to recognize the existence of Permian rocks in that section, and the classic paper by Swallow and Haun on the Kansas Permo-Carboniferous will be referred to by future geologists as long as the science is studied.

The third geological survey of Kansas was authorized by the law of 1889, and the organization effected in 1895. The survey is intimately connected with the state university and the Chancelor of the University is ex officio Director of the Survey. Erasmus Haworth who for many years was head of the department of geology, served as state geologist, and it is due largely to his efforts that the survey has been a success. During the

past year, he has been succeeded by W. H. Twenhofel, and is devoting himself almost exclusively to the work in the department.

During the administration of Dr. Haworth, nine massive volumes were issued, dealing with all phases of Kansas geology. The reports by Williston on Cretaceous Vertebrates, by Prosser on the Permian, by Bailey on mineral waters, by Beede on various subjects, and by Cady and Bushong on oil and gas analysis, are of a very high order. The state of Kansas owes much to Erasmus Haworth for the work he has inaugurated and carried forward.

Arkansas.

The first geological survey of Arkansas was established in 1856. David Dale Owen, who was then state geologist of Kentucky, was appointed state geologist of Arkansas and served until his death in 1860. Two reports were issued, both of a reconnaissance nature. This survey was terminated by the Civil War.

After the close of the war several attempts were made to resurrect the survey, but it was not until 1871 that an appropriation was finally made. Between 1871 and 1875, four men served as state geologist, namely, W. F. Roberts, Geo. Haddock, W. C. Hazeldine, and Arnold Seaburg. Very little work was done by any of these men and no reports of lasting value were issued.

The third geological survey, usually known as the Branner survey, was organized in 1887, and John C. Branner was appointed state geologist. The work done by this survey was of high order. Thirteen reports were issued, dealing largely with the various economic products of the state. Dr. Branner, who for many years has been at the head of the department of geology at Leland Stanford, and during the past year President of that University, is a man of very strong presonality, and the stamp of his work still remains on the state where he labored for so many years. He was, however, a better geologist than politician, and failed to secure sufficient appropriations to continue his work, because the "survey had declared fraudulent certain so-called gold mines in the western part of the state."

The present survey, the fourth, which has been in operation in Arkansas, was established in 1907. It is in charge of

a commission composed of the Governor, the President of the University, and the Commissioner of Mines and Manufactures. A. H. Purdue, who was at the same time professor of geology at the University, was state geologist from 1907 until 1913, at which time the legislature exercised its prerogative of failing to appropriate money for the maintenance of the survey. Professor Purdue resigned and has since been serving as state geologist of Tennessee. N. F. Drake, his sucessor in the University, is nominally state geologist, but is usually without funds for work.

Texas.

The first geological survey of Texas was organized in 1858, and B. F. Shumard was appointed state geologist but served only two years, when he was suspended for political reasons by that arch politician, Governor Sam Houston, and Francis M. Moore a man totally without qualifications except the ability to pull wires, was appointed in his place. This survey passed out of existence in 1867, and it was not until 1870 that the second Texas survey was inaugurated. J. W. Glen and S. B. Buckley, neither of whom had standing as geologists, served as state geologists until 1877 when this survey also ceased to exist.

The third Texas survey was organized in 1888 and was in existence until 1892. E. T. Dumble was appointed state geologist. Ample appropriations were made and considerable work of high grade was accomplished. Much of the early work of Robert T. Hill on the Cretaceous was done under the Dumble survey. The work of Cummins on the Permian in northwestern Texas, and of Drake on the Triassic will always remain classic. Mr. Joseph A. Taff began his geological work at this time and the work of Von Sterwitz and others will long be remembered. A number of volumes were issued dealing with various scientific and economic phases of the geology of Texas. It is said that the fall of the Dumble Survey was due to a speech made in the Texas legislature by a "horny handed son of toil," who claimed to have surprised some member of one of the field parties fishing, and afterwards searched the auditor's books and found on file an item of 25c spent for fish hooks.

During the years 1901 to 1905 there was carried on the University of Texas Mineral Survey, of which Dr. Wm. B.

Phillips was director. The present style of the survey is the Bureau of Economic Geology and Technology of the University of Texas. It is under the general direction of the President of the University and the funds are included in the University budget. Wm. B. Phillips, now president of the Colorado School of Mines, was Director of this bureau from its organization in 1909 until 1915. The work has been largely economic and a number of important bulletins have been issued dealing with the fuels, iron ores, the various oil fields of the state, as well as several scientific bulletins written by Dr. J. A. Udden, the present director.

Oklahoma.

In geology as in many things, Oklahoma is an example of arrested development. Long after the states to the north, east and south of her, had had their political, social and educational functions in operation, Oklahoma remained untouched and undeveloped. This was the Indian's land and the white man was not welcome. Not until 1899 was the Anglo-Saxon permitted legally to set foot in Oklahoma, and it was less than a decade ago that the boon of statehood was conferred upon the people. All of which, being interpreted, means that geological work in this state was long delayed. Neither a state survey, nor work by men in local institutions was possible for nearly 50 years after similar work had been undertaken in adjoining states.

So far as I have been able to learn the first scientist of any national reputation who visited Oklahoma was not a geologist, but a botanist, Thomas Nuttall, who in 1819 accompanied Major Bradford from Fort Smith up the valley of the Poteau River, across the Kiamichi Mountains to Red River. Professor Nuttall also made an expedition to the Verdigris River where he visited a salt-making plant.

The first geological work in the state was at the time of the noted Red River expedition conducted by Captain R. B. Marcy with Geo. B. McClelland second in command. The object of this work was to discover the head of Red River. This expedition which started from Fort Belnap, Texas, in 1852, entered Oklahoma near the mouth of Cache Creek, passed through the Wichita Mountains, noting the granite peaks, and first studied the gypsum deposits on the North Fork of Red

River, south of what is now Elk City. Mt. Scott was first named by Captain Marcey at this time; as also was Mount Webster, now known as Tepee Mountain. The surgeon of this expedition was G. C. Shumard, who collected fossils and rock specimens, which were afterwards identified by other men. The paleontology was done by Dr. Shumard's brother, B. F. Shumard, afterwards state geologist of Texas, and the geology by Professor E. Hitchcock, president of Amherst College.

The first bonafide geologist of whom I can find a record, who crossed what is now Oklahoma, was Jules Marcou. This noted Swiss geologist, was one of the famous quartet of scientists, composed of Louis Agassiz, zoologist, Leo Lesquereux, James Goyot, and Marcou, all young men who were driven to America by one of the European wars of the middle part of the nineteenth century. Marcou was the scientific member of an expedition which in 1855 crossed the Great Plains, searching for a route for a railroad to the Pacific Ocean. In his report Marcou mentions the coal fields near Fort Smith and in what is now the McAlester country. The expedition passed up the Canadian River, probably along the divide south of the river, keeping west between the South Canadian and the Washita. It was Marcou who first found Cretaceous oyster shells in what is now Washita County, Oklahoma.

For several decades there was no systematic work of any kind done in the state. Occasionally some geologist from Washington, D. C., or from some adjoining state would cross the border and make certain observations in Oklahoma, part of which have found their way into print. Edward D. Cope, of Philadelphia, the noted vertebrate paleontologist, discovered Tertiary and Pleistocene vertebrates in the Texas panhandle and the extreme western Oklahoma. John J. Stevenson of New York, made one or two trips to this region in the early nineties and wrote concerning the Coal Measures rocks. T. Wayland Vaughan accompanied Robert T. Hill on one of his trips and redescribed the Cretaceous shell beds in western Oklahoma, first discovered by Marcou. Certain of the Texas geologists examined the Arbuckle and Wichita Mountains, but for the most part nothing of importance or of lasting value was accomplished.

Some of the first systematic work in Oklahoma was done by the noted Texas geologist, Robert T. Hill, on the Cretaceous

deposits in the southern part of the state. Mr. Hill a native of Texas, and a graduate of Cornell, is a man whose name is so deeply graven on the history of the geology of his native state that scores of generations may not eradicate it. In the middle eighties Mr. Hill began publishing on the geology of Texas, and in 1888 he published an article entitled "Trinity formation of Arkansas, Indian Territory and Texas." One of the three great divisions of the Comanche Cretaceous, now famous in geological literature, is the Washita division named from the Washita River of Oklahoma. Mr. Hill's monumental work was entitled "Geography and Geology of the Black and Grand Prairies of Texas," which appeared in 1901, and summed up the results of his work on the Cretaceous. During the years he worked in Texas, he contributed to the various journals a great number of articles dealing chiefly with the Cretaceous of his state, but many of his papers have more than incidental references to Oklahoma. For many years Mr. Hill was a member of the United States Geological Survey and is now practicing his profession as a mining engineer.

Another name intimately connected with that of the early history of geology of Oklahoma is that of Joseph A. Taff. Mr. Taff, who is a graduate of the University of Arkansas and of the University of Texas, did his first geological work as a member of the Dumble survey. He afterwards became a member of the United States Geological Survey, and beginning about the year 1895, spent more than 10 years in studying the geology of the eastern part of Oklahoma. While the greater part of the work was confined to the coal fields, he at the same time, worked out in considerable detail the structure of the Ouachita, Arbuckle and Wichita mountains, as well as that part of the Ozark Range which extends into northeastern Oklahoma. Besides numerous general reports, dealing with the coal and asphalt deposits of the eastern part of the state, he published five folios, namely Atoka, Tishomingo, Coalgate, Tahlequah, and Muskogee quadrangles, as well as Professional Paper No. 31, which is still our best authority on the geology of the Arbuckle and Wichita mountains. Mr. Taff has named and described more different geological formations in Oklahoma than any other man. For a number of years, Mr. Taff has been in the employ of the Southern Pacific Railroad, with headquarters at

San Francisco. Associated with Mr. Taff at various times in his work in Oklahoma have been such geologists, as E. O. Ulrich, David White, Geo. H. Girty, Geo. I. Adams, Sidney H. Ball, and others. Among other men who have published articles on the coal fields of Oklahoma, the names of N. F. Drake, now state geologist of Arkansas, and H. N. Chance should not be forgotten.

Another name which will always be connected with the early geology of Oklahoma is that of F. W. Cragin. Professor Cragin was at one time teacher of science at Washburn College at Topeka, Kansas, and while there wrote a number of papers connected with the geology of the southwestern part of that state, especially the Cretaceous deposits near the town of Belvidere, at the head of the Medicine River. He also published in 1896, an article entitled the "Permian system of Kansas," and the next year a paper entitled "Observations on the Cimarron Series." In these two papers he described and named a number of different formations in the Red Beds series and first used such names as Medicine Lodge, Shimer and Bay Creek, which names will always remain as part of the nomenclature of the Red Beds.

The first official recognition given to geology by the territory of Oklahoma, was in the year 1889. At that time a law which had been prepared largely by David R. Boyd, president of the University of Oklahoma, was introduced into the Territorial legislature establishing the Geological and Natural History Survey of the Territory of Oklahoma, and appropriating for its maintenance the munificent sum of $200 per year. Under the law the professor of Biology at the State University was ex officio Territorial Geologist. Prof. A. H. Van Vleet, was at that time head of the department of Biology and became Territorial Geologist in 1898, serving in that capacity until at the time of statehood in 1907. Considering the small amount of money available, the results of this survey were very satisfactory. From 1901 until 1908 parties were in the field each summer, and two volumes, known as the Second Biennial and Third Biennial reports were issued, dealing with the general geology and resources of the territory. The Second Biennial Report of the Territorial Survey contains the first attempt at a description of the geology of the territory, also an article on the gypsum

deposits. Lists of birds, plants and snakes of Oklahoma were also published.

In 1905 a report entitled "Geology and Water Resources of Oklahoma" was issued as a water supply paper of the United States Geological Survey, which dealt with the geology and underground water resources of Oklahoma Territory.

Oklahoma is the only state in the Union that contains a constitutional provision for the establishment of a geological survey. The survey which was established in 1908, is under the control of a commission consisting of the Governor, the State Superintendent of Public Instruction, and the President of the State University. The commission appoints the Director, who selects his assistants. Three men have served as director of the survey; the present writer, D. W. Ohern, and C. W. Shannon. Assistant directors have been L. L. Hutchison, L. C. Snider, L. E. Trout, and Geo. E. Burton. Several geologists of note have at various times assisted on the Oklahoma Geological Survey. Among others may be mentioned, J. W. Beede, Chas. H. Taylor, Chester A. Reeds, and Irving Perrine.

Among the younger men who received at least a part of their early training on the Oklahoma Survey and who are now pursuing geology as a vocation, I happen to remember Pierce Larkin, Frank A. Herald, H. A. Everest, E. L. DeGolyer, Everett Carpenter, Roy Hazeltine, C. W. Hamilton, Robt. H. Wood, John Herald, J. B. Newby, Glenn Clark, Robt. E. Garrett, Burr McWhirt, Frank Buttram, Geo. H. Burress, Wm. A. Buttram, Geo. Morgan, Fritz Aurin, Geo. H. Meyers, Harve Loomis, B. F. Wallis, Don Walker, C. R. Thomas, Dean Stacy, Richard A. Conkling, and Russell Crabtree.

The survey has published some 25 volumes dealing largely with various economic resources of the state.

In addition to the work in the various states, which has been accomplished from time to time in the Southwest, the United States Government has been active in this region. The topographic branch has surveyed a considerable part of the territory in each of the states mentioned. Topographical maps have been prepared of about two-thirds of the state of Missouri, three-fourths of the state of Kansas, a little more than half of the state of Oklahoma, about one-third of Texas, and approximately half of Arkansas. Folios have been published on the

Fayetteville and Winslow quadrangles in Arkansas, on the Tahlequah, Muskogee, Coalgate, Atoka and Tishomingo quadrangles in Oklahoma, on the Austin, Llano, Burnett, Uvalde, Nueces, Van Horn and El Paso quadrangles in Texas, on the Cottonwood Falls and Independence quadrangles in Kansas, besides the Joplin sheet of Missouri and Kansas.

A number of water supply papers have been published dealing with the various states, particularly those by Gordon, Taylor, Deussen, and the writer in Texas; Shepard in Missouri; Haworth, Slichter, and Parker in Kansas; and the writer in Oklahoma.

Among the professional papers dealing with the Southwestern country may be mentioned the report by Adams and others on the lead and zinc deposits of northern Arkansas; A. C. Veatch's paper on the geology and underground resources of Arkansas and Louisiana; Mr. Taff's work on the Arbuckle and Wichita mountains, L. W. Stevenson's contribution on the Cretaceous-Eocene contact, and, of course, Bailey Willis's monumental work on the Stratigraphy of North America. Numerous government bulletins have appeared dealing with the geology of the Southwest. Of more than fifty separate publications of this character, those of most interest to the oil geologist are the Munn and Wegemann bulletins dealing with the geology of southwestern Oklahoma, as well as those by Kennedy, Fenneman and Harris, dealing with the oil on the Coastal Plain.

COASTAL SALT DOMES.

By WILLIAM KENNEDY, *Fort Worth, Texas.*

(Tulsa Meeting, February, 1917.)

The geology of the gulf coastal zone while extremely interesting is at the same time somewhat hard to decipher. Outside of a few mounds and salt domes showing at intervals, there is nothing indicative of what the underground conditions may be. Throughout the whole length of this zone, which may be said to extend from the Mississippi River westward across the states of Louisiana and Texas, and for many miles southward into the Mexican State of Tamaulipas, and for a width of more than fifty miles, there is nothing but the same uniform flat prairie interspersed here and there with small mottes of trees or narrow strips of small timber fringing some of the streams. The only difference in conditions seen in the whole extent of this territory is that throughout the eastern portion as far west as the Colorado River the country is mostly low lying and marshy. West of this river the country becomes more sandy, the sandiness increasing as we go south and west until in Cameron County in Texas and Tamaulipas in Mexico, it may be said, the whole region is nothing but a sandy desert occupied by an arid sandy country flora.

The streams flowing across the region, with the exception of some of the larger rivers, are mostly sluggish, flowing through tortuous channels, some of which are merely waterways in the midst of broad stretches of marsh. Even the larger streams such as the Trinity, Brazos, and Colorado, together with the Neches and Sabine in Texas; the Calcasieu, Mermentau and bayous in western Louisiana wander backward and forward in many places, and some, like the Calcasieu and Mermentau, spread out in places and form broad shallow lakes. In a number of places even the larger rivers have more than once changed their courses, leaving their former channels in the shape of chains of long narrow lakes. The greater number of these bayous, as well as the rivers, are submerged channels having

their bottoms many feet below the present level of the gulf and are filled to a considerable depth with salt water. This condition is particularly true in southern Louisiana and southeastern Texas as far west as the Colorado River. West of this the streams are of less depth and less affected by the tidal waters of the gulf.

Some idea of the general flatness of the region may be obtained from a study of the lines of railroads traversing the region. Thus the Frisco Lines from Baton Rouge westward through Beaumont and Houston to Brownsville lying at an average distance of a little over fifty miles from the coast show only four points having an elevation of over 70 feet above sea level. The Sunset Central Line from New Orleans to Houston reaches an elevation of 80 feet at only one point—Dayton—but at no other point do these lines reach an elevation of over 50 feet.

The numerous surveys for rice canals anl levees have shown the general slope of the region coastward to be from ten inches to a foot per mile, except in the immediate vicinity of the river channels, and in these the slope is much less.

Under these conditions it is extremely difficult to say what may be the conditions of the underlying beds. No exposures of them occur anywhere within the coastal region, even the exposures along the larger rivers show only a small section of the heavy mantle of recent or late Pleistocene deposits. It is only through a close study of the records of the wells drilled within the region and their contained fauna that any knowledge of the region may be obtained.

These underlying formations were apparently subject to numerous oscillations and to obtain some idea of these we may go back to the marine conditions of the Upper Cretaceous. The conditions existing in Wilcox time appear to have been mostly coastal marsh or swamp, partly fresh water and partly marine. Following these come the marine shore-like conditions of the Mount Selman-Cook Mountain time. Next we have brackish and freshwater conditions of the Yegua. This was followed by the partly land and partly marine period of the Fayette, changing again to the brackish water conditions of the Jackson in the eastern portion of Texas. Then comes

the land or fresh water Catahoula to be again followed by the brackish or salt water period during which the Fleming beds were laid down.

This condition appears to extend throughout western Louisiana and eastern Texas as far west as the Brazos River. West of that stream very considerable changes appear to have taken place and many of the clayey formations found throughout the eastern portion of the state here begin to assume a more sandy phase and in many localities lie tilted at considerably higher angles than in the east. Throughout the region lying between the Brazos and Colorado rivers three subdivisions have been introduced,—these are known as the Oakville sands, Lapara sands and Lagarto clays. It is probable some, if not all of these, may be correlated with some of the various phases of the Fleming beds. In the Navasota region the so-called Navasota phase of the Fleming beds consist of blue calcareous clays, calcareous sands and soft sandstones carrying bones and rolled cretaceous fossils. The Oakville beds may be said to have the same structure and carry the same character of fossils. The Lapara sands also carry small fragments of bones and some fresh water unios. The overlying Largato clays are essentially blue and yellow clays with numerous calcareous nodules. These Oakville beds are very irregular in structure, show the sorting of water action, and present the appearance of having been deposited in rather shallow turbulent waters such as might occur along an open coast line subject to violent storms or tidal work. Or, they may have been deposited in stream channels where the waters were intermittently rapid and slow. They appear to be mostly of fresh water origin. These Oakville beds extend as far west as the Nueces River beyond which their existence is obscured by the Reynosa limestones.

Throughout the region between the Brazos and Colorado rivers the brown gravels of east Texas begin to show an intermingling with the black flinty gravels and calcareous materials of the Reynosa of the west. Toward the east we have the brown cherty gravels showing an easterly thickening, while toward the west we have a gradually increased thickening of Reynosa material.

Taken all together, it looks as if this region from a few miles east of the Brazos River to a few miles west of the Colorado

River formed the divide separating the Mississippi embayment from the embayment belonging to the Rio Grande, and it may be, the peculiarities of structure found in this region have been more or less influenced by this condition.

On entering the Rio Grande embayment we find sandy materials forming the prevailing deposits. The general section on the Rio Grande is in close concordance with the section in East Texas, with the exception of the introduction of a series of green colored clays known as the Frio clays. These clays have been considered the top of the Eocene in this region.

Owing to the conditions prevailing throughout this portion of the state very little definite information regarding it can be obtained. It may, however, be definitely stated that the Fayette, Yegua and Cook mountain formations are present and extend at least fifty miles down the Rio Grande from Laredo. These formations also show on the Mexican side of the river for a good many miles. Much of this region, it may be said, is obscured by the presence of the Reynosa limestone and its associated gravels. This is particularly so on the Mexican side.

During all the movements which brought about the changes noted, the region was subjected to a considerable degree of warping and bending and probably more or less faulting although this latter would hardly be of great extent as the soft pliable conditions of the beds would enable these to adjust themselves to the changing conditions brought about by each change of level.

That these oscillations were severe at times is shown by the finding of Jackson fossils at Sour Lake, according to Harris, at depths ranging from 1000 to 1500 feet and at Saratoga at a depth of 1645 feet. Wells between these points drilled to 2000 and 2200 feet found no Jackson formations. Harris claims to have found Oligocene fossils overlying the Jackson at Sour Lake, but no Oligocene whatever has been found at Spindletop, Batson, or Saratoga. Dall has described Miocene fossils at depths of from about 800 to 1800 feet at Spindletop, 800 to 1200 feet at Saratoga and about 333 feet at Batson. Brackish water late Miocene, or early Pliocene fossils have been found on the surface at Burkeville, at 3200 feet at Terry, 3000 feet at Edgerly, 1545 feet at Pine Prairie and 1500 feet at Anse

la Butte. A well drilled twelve miles north of Terry, between Terry and Burkeville, to a depth of over 3000 feet did not enter the formation carrying the Terry fossils. Late Miocene, as well as Pliocene fossils, also occur at Hoskins Mound, Bryan Heights and at Markham.

In addition, the same fossils found in the Galveston well at about 2200 feet were seen in the wells at Goose Creek a little below 1600 feet and in a well near Olivia in Jackson County at 600 feet. Fresh water Pliocene fossils were obtained from a well near Columbia from a depth of a little over 400 feet and fresh water shells were also found underlying a salt water fauna in a well in the upper portion of Chambers County at a depth of 1000 to 1200 feet. Pliocene vertebrates, equus, were found at a depth of 400 feet at Hoskins and what Dr. Mathews considered a vertebrae of a young proboscidian came from a depth of 100 feet at Markham.

It is probable these oscillations were irregular in some places, being more rapid than at others. They were, in all probability, slow enough to enable the larger rivers to maintain their channels. This condition existed at least on the Brazos as it has been shown by some recent drilling that that river has maintained its channel through a depth of over 1200 feet.

To whatever extent these movements may have occurred it is certain that the beds involved never returned to the condition they were in before the movement took place and each succeeding bed or formation was laid down upon the uneven somtimes highly eroded surface of the preceding one, and at a different dip.

It is probable the latest member of the Coastal Deposits, the Beaumont clays were laid down upon such a floor as this. These clays are very widely spread and may be said to cover the whole of the coast country from near the Mississippi River westward at least as far as Brownsville, and may probably pass out of sight somewhere near the San Fernando River in Mexico. If we eliminate a few ridges of wind blown sand in the neighborhood of Alvin and El Campo and the thin sandy covering found in the lower Rio Grande and Mexican district, which may also be considered as being to a great extent wind blown, the Beaumont clays may be said to form the surface of nearly the whole country.

These clays are yellow, blue, brown and black in color with brown and gray sands. There are occasional deposits of red clay. These beds are sometimes thinly stratified or laminated and frequently massive The laminated beds are usually interstratified with thin beds of blue and gray or grayish white sand. The clays carry considerable quantities of calcareous nodules irregularly distributed in many places, shells of Pleistocene or Recent age and great quantities of decaying wood. Of these plant remains the Cypress appears to be the most prominent, and among the invertebrates, the Rangia Cuneata, Rangia Johnsoni and an undetermined oyster are the prevailing forms. In these clays the calcareous nodules do not appear to have any definite position. Towards the upper surface and for several hundred feet the lime appears almost altogether in the form of a carbonate, but with depth, the carbonate gives place to sulphate and small isolated nodules of amorphous gypsum and small crystals of selenite are by no means rare. In some localities drilling has shown these gypsums to lie in beds from two to four feet thick but their areal extent is usually very circumscribed.

Wood is abundant throughout these clays. This often shows in an almost fresh condition as if it has been buried but a short time. In others the decay may be said to be almost complete and in some places, particularly in the vicinity of the domes the wood may be described as carbonized but not lignitized. Throughout the whole formation the wood is never silicified. In this respect it is entirely different from any fossil wood found in the underlying formations.

The generally low flat condition in which these Beaumont clays occur renders any attempt to unravel their structure with any degree of certainty somewhat difficult. They are by no means structureless as the whole body of the beds carry sands occupying very irregular positions and lying in very irregular forms. Drilling has shown some of the sands to lie in the shape of short, rather mound like bodies, others elongated and rather thin, while yet others form regular beds extending a mile or more in length. The clays themselves are irregular and in places they occur in a massive form giving rise by their toughness and tenacity to the term "Gumbo" so frequently used by drillers. Often within the middle of these "Gumbo" de-

posits, pockets of thinly laminated shaly looking clays occur, sometimes intermixed with laminae of sand and frequently carrying small quantities of oil. These are the shales and "oil shows" so frequently recorded in the logs of the wells drilled throughout the region. These pockets of shale while numerous are by no means regular as to extent or horizon. In some wells they may occur several times, while in the neighboring wells they are absent.

Throughout the whole of the area occupied by these Beaumont clays the only means of obtaining any information regarding their structure or thickness is by means of wells drilled in the search of oil. Unfortunately few of the logs are kept with any degree of precision. The records rarely show the color of the material passed through, or the character of the rock encountered, when such is met with. These conditions often render it difficult to determine to what division the materials passed through, belong. However, as the Beaumont clays carry but very little gravel and the sands are usually thin the appearance of heavy gravels, sands and rock shows that the drill, in all probability, has encountered some underlying formation.

Attention must, however, be drawn to the fact that as the Lafayette extends seaward it loses much of its landward structure. In its seaward extension it assumes more clayey and sandy phases, the gravel deposits gradually become thinner and finally disappear, the sands thicken to some extent, but even these in a great measure, lose their identity and become sandstones which eventually lose themselves in a clay.

Lying at the base of the Beaumont clays, but probably belonging to and forming a phase of the underlying Lafayette, we find a heavy bed of very fine sand which appears to be flowing south at the rate of about an inch a year. This sand was found in a number of wells in the Saratoga field at a depth of approximately 800 feet. Its presence is demonstrated by the peculiar bending and breaking of the well casings at that depth. Some of the casings were broken and the upper portion pushed over, others, although not broken, were bent so that it was almost impossible to get the tubing down below this point. The same conditions were found in wells drilled in Orange County, at Spindletop and other places.

Gas Mounds.

Another peculiarity attached to these heavy dark clay beds is the presence of the so-called gas mounds. These mounds are small and usually rounded, but often slightly elongated and made up mostly of a light grayish sand, usually accompanied by small calcareous nodules and sometimes small quantities of water. They do not appear to be scattered promiscuously over the face of the country, but lie in regular belts and these belts, while interrupted in many portions of the region, appear in many localities. Nowhere do these mounds appear except within the area covered by the heavy clays of the Beaumont formations.

Much discussion has arisen as to the origin of these mounds. They have had a number of theories applied to them. Without advancing any theory as to their origin, it may be pointed out that they are wholly indigenous to the Beaumont clays and within the coast country appear nowhere else. These Beaumont clays carry beds of sand often extending over considerable areas, but these sands cannot be considered in any way as being continuous as in many places the beds are interrupted by heavy deposits of clay. These sands are moreover irregularly distributed in the form of lentils throughout the clay. The clays themselves are often highly calcareous and carry great quantities of wood from the almost fresh timber itself to the carbonized but not lignitized wood such as has been found in the wells drilled in the vicinity of Bryan Heights and other mounds of that type. In the gas mounds the structure is amorphous or rather, no structure has been observed. These mounds are invariably composed of very fine grained sand with some calcareous matter intermixed or in the form of small calcareous nodules. A few have been drilled into and the drill has shown them to be a pipe, or formed completely of sand at least to the depth of the first big sand. Below this sand clays occur. Where no sand occurs within a shallow depth there are no mounds. Occasionally, especially in the vicinity of the large mounds such as Spindletop, Dayton and some others, these small mounds appear to encircle the larger ones.

It might be inferred that when the clays were being laid down large quantities of vegetation were deposited with them and with the decay of so much material, there can be no doubt

but that large quantities of gas were evolved. Some of it may have reached the surface and escaped, but a considerable quantity was occluded in the clays or escaped into adjacent sand and was there confined.

This gas probably in association with water forced the sand upward and formed the mound. During this process the sand would be brought close to the surface but held under by the overlying clay. The mounds being more prominent than the other portions of the surface would naturally be more exposed to erosion and after a time the thin coating of clay would be worn off and the formation of the mound would cease.

Gas continues to escape from some of these mounds. In the early Spindletop days, before drilling had progressed very far, it was noticed that wherever these mounds occurred upon or around the hill, there was an escape of gas. In the Dayton region escaping gas was plentiful and strongly in evidence in the small mounds in the vicinity of the main mound, but when active drilling commenced the flow of gas through these mounds ceased.

The more probable solution of the question of the formation of the small mounds is that they were formed by the action of gas probably accompanied more or less by water. During the latter period of the deposition of the Beaumont clay the country was covered by a thin deposit of clay, or more probable, soft mud. The generation of gas took place at a lower depth or in close association with the vegetable matter enclosed in the clay and also in some of the sand. The gas found its way into the sandbars and as these lay within a short distance of the surface, the force of the compressed gases lifted the clay surface into gigantic bubbles, if such a term may be used. Undoubtedly many of these bubbles may have burst allowing the gas to escape, but at the same time a great many may have resisted sufficiently to remain solid and with the drying of the muddy or clayey surface the form of the mound remained fixed. The gas and associated water when forcing up the clay, at the same time raised the sand and filled the clayey shell. With the elevation of the surface these mounds, being the highest ground, would be the first affected by erosion. The thin clay or hard shell would be worn off, thus exposing the sand and giving the gas free access to the air. Along with the gas came more or

less limey material probably in solution and when this reached the zone of carbonizing influence the lime would be precipitated in the form of the nodules of calcareous material found so prolifically around these mounds. It may also be noted that the sand forming the mounds is all more or less calcareous and this condition may have given them a stability which they otherwise would not possess. While these small mounds are undoubtedly in close association with the large mounds, they are also found in many other places and can in no manner, notwithstanding popular opinion, be considered as indicators of the presence of oil at depth. Numerous dry holes are witness to this condition.

Mounds.

While these small mounds cannot possibly be considered as having any relation to the oil bearing features of the coastal country there is another set of mounds or "Domes," as they are usually called, whose method of formation and structural conditions are much different from the small mounds. It may be noted that while these mounds occur throughout the whole of the Gulf Coast from the Mississippi River on the east to and beyond the Rio Grande on the west and extend inland for a distance of fifty miles, the greater number of them are grouped within the area occupied by the Beaumont clays. Some of these stand up very prominently; others, although distinguishable, are not so prominent; while a third series are scarcely preceptible except by careful measurement or by drill records.

These mounds have been aligned in several ways, the general concensus of opinion being that they should be aligned in a general northeast-southwest direction or practically following the coast line. There have been various views held as to the relationship they bear to each other. From investigation it may be broadly stated that these are all of the same age and of the same general structure, but in the absence of any deep drilling along the lines in which they may be supposed to be connected, it is difficult to prove any connection. Still it may be pointed out that in some cases a strong similarity, at least, of some of the drillings at considerable distance from the dome with those on the dome is somewhat suggestive. In the Golden Flow well nearly two miles west of the Spindletop, limestone was found at 1877 feet and a mixture of lime, sand and clay at 2700 feet.

The same materials with the addition of gypsum and gas were found in the bottom of this well at the depth of 3284 feet. On the western side of Humble, at least two miles from the core of the dome, in the Motex Company's well, 21 feet of gypsum were found at 1942 feet and again ten feet of the same material were passed through at 2015 feet. The gypsum, lime and other dome building materials were also found at a depth of about 2600 feet, and on the northeastern side of Hoskins Mound, 45 feet of gypsum and sulphur were found at 1791 feet. This well is over a mile northeast of the mound.

The distance between Hoskins Mound and Bryan Heights is only twenty-four miles. Halfway between these two domes is another elongated ridge known as Stratton's Ridge. This ridge lines in a general northeast-southwest direction, or in a line which if extended would pass through both Hoskins and Bryan Heights. A heavy deposit of lime and gypsum is found in this ridge at a depth of 800 feet. The surface elevation of all three of these localities is within a few feet of being uniform. The rock salt found at Hoskins Mound was entered at about 1000 feet and at Bryan Heights it was found at about the same depth. Whatever may be the conditions along the northern slope of this line it is known that the southern slope pitches rapidly. A well drilled about 1000 feet from the southern side of Hoskins Mound found clay and sand at 1800 feet, at Stratton's Ridge a well nearly a mile to the southeast of the crest of the ridge found sands and clays down to the depth of over 2,000 feet. No deep drilling has been carried on to the south of Bryan Heights, but operations carried on in the prospecting for sulphur shows the mound building material plunging rapidly in that direction.

In addition we have a set of what may be termed buried mounds. Of these we have little or no evidence on the surface and those so far known have been brought to light mostly by the operations of the drill. Some of them have been outlined by the drill and their under-ground conditions are fairly well known. Others are only partly known; in fact, beyond their existence very little is known about them. These obscure mounds lie almost directly in line with the more prominent mounds and so far as known all have the same structural char-

acters, that is to say, they are made up of limestones, gypsums and salt. Some small quantities of sulphur and petroleum accompanied by large volumes of hydrogen sulphide have been met with in these mounds.

Probably the best examples of buried mounds are Bayou Bouillon in Louisiana, and South Dayton and Hockley in Texas. Bayou Bouillon lies in the drainage area of the Atchafalaya River and throughout the greater portion of the year the region is under water. The only indication which led to drilling in this area was the presence of gas rising through the water of the Bayou. Three hundred feet of limestone were found at a depth of 1900 feet and rock salt at 2200 feet. In the Texas region, South Dayton and Hockley are probably the best examples of buried domes. South Dayton has been described as a flattened salt deposit having a broad top with sharply dipping sides. Although the salt deposit is known to occupy an area of something like four square miles and to have a thickness of over 2000 feet, not a sign of this dome appears anywhere on the surface. It lies within the flood plain of the Trinity River and the presence of a small quantity of sulphur water led to its exploitation. Hockley is another of the buried mounds in which sandstones and limestones were found from about 450 to 900 feet and salt at about 1000 feet with no indications of its existence being seen at the surface. A small show of gas found in some of the deeper water wells led to drilling.

From their general location in line with the prominent mounds and the general similarity of structure of these buried mounds, the question may be asked what is the relationship between the buried and visible sets of mounds, if any? Are they of the same age and if so, what are, or were, the causes that brought some to the surface so prominently while others were held back and remained in the position now found? Or are the buried mounds of a much younger age? These are questions that may never be settled satisfactorily, but it is clear that whatever may have been the forces operating in the formation of the one, the same forces were equally active in the formation of the other, but probably at a much later period.

From these conditions it will readily be seen that the east-west direction is the logical course to align these mounds.

Structure of the Mounds.

As a general rule these domes have a core of rock salt which in turn appears to be overlain by gypsum, dolomite, clays, and sands. In some of the lower domes gravel is found in the drilling on top of the mound, but in some of the more prominent domes the gravels occur in considerable quantities around the side and not on the top, indicating that such a mound was in existence prior to the deposition of the gravel. The almost universal presence of salt in these domes has given them the distinctive name of "saline domes." In addition to the salt and gypsum some of these domes have developed large quantities of sulphur.

Some of the domes appear to be quaquaversal, others are elongated and lie in a form of a broken anticline and when considered as a whole, most of the lines of domes look as if they were all portions of a very long fold or anticline. Welsh is a type of a dome in the form of a narrow uplift with very sharp dips both on the north and south side, the northern dip being somewhat sharper than the southern slope. This dome or uplift trails off with gentle dips toward the northeast and southwest. No salt has yet been seen although wells having depths of 2550 to 2600 feet have been drilled on top and along both sides of the uplife. Saratoga appears to be a double dome or fold; that is, there is a hollow or sharp depression extending in a general east and west direction through the center of the dome. Batson shows the same structure although in a modified form. The same structure also appears in the western end of the Blue Ridge in the Missouri City district. The Dayton uplift appears to be a low wide uplift, while South Dayton appears to be a flattened salt deposit having a broad top with rather sharply dipping sides. Sour Lake appears more in the form of a depressed or sunken topped dome.

Faulting does not appear in connection with these mounds but drilling has shown a fault to exist in Damon Mound and it is very probable a fault occurs at High Island, where the northern end of the Island shows immense deposits of gypsum while rock salt occupies the whole of the southern end. It is between these two that the springs forming the "trembling marshes" break out.

During the early days of drilling on these mounds the drillers frequently asserted they passed through large boulders and more than once the drill was twisted off by being caught in a crevice. As the boulders often extended over two or three locations and the crevices were narrow and not very deep it looked then that the uppermost beds of limestone were more or less fractured and the crevices represented the breaks. These conditions occurred at Spindletop, Hoskins Mound, Bryan Heights, Columbia, and at other localities in a minor degree.

Materials Forming Domes.

The structural materials forming these domes are similar in every one from Sulphur Mines westward to Bryan Heights and Damon Mound. These sands and clays, limestones and gypsums intermingled more or less with sulphur and rock salt, all lie in the same relationship to each other. In some of these mounds large volumes of oil occur, while in others but very small quantities are found. Immense volumes of hydrogen sulphide and sulphuretted waters accompany these mounds. The associated waters and gases flow from the wells at very high temperatures. Only a few have been measured. The temperature of the water issuing from the opening at Sulphur Mine is about 100° F. and at Vinton 100° F. At Spindleton these waters ranged from 99° F. to 120° F. and at Bryan Heights 160° F. It may be noted, however, that many of the other mounds throughout the coast country produced water ranging from 116° F. at Batson to 180° F. at Saratoga.

These mounds are all domes of a more or less quaquaversal type. This feature has been worked out at Sulphur Mines, Spindletop and other localities. They appear to have very high dips or probably more correctly speaking, very strong slopes. At Sulphur Mine the slope is about 4000 feet to the mile along the north and northeast sides, but on the southern margin the slope, although standing at a high angle, is not that much. At Vinton the slope is at a high angle but not quite as great as at Sulphur Mine. At Spindletop, Big Hill in Jefferson County, as well as Barber Hill and other mounds, the drilling has shown the same character of sloping sides.

For the purpose of comparison a generalized section of Sulphur Mine on the east and Bryan Heights on the west is here given:

Sulphur Mine.

Clay, Quicksand and Gravel	0-445 ft.
Dolomite	445-487 ft.
Sand with crystals of sulphur	487-505 ft.
Sulphur and Gypsum	505-546 ft.
Pine Sulphur	546-568 ft.
Sulphur and Gypsum	568-604 ft.

Bryan Heights.

Clay, Sand and Gravel	0- 680 ft.
Blue Limestone, Gumbo, with some oil	680- 762 ft
Gypsum with Sulphur	762-1090 ft.
Gypsum with Sulphur	1090-1113 ft.
Rock Salt	1113

This section may be extended towards the west through Big Hill in Matagorda County to and beyond Piedras Pintas in Duval County and eastward to Bayou Bouillon in St. Martin Parish in Louisiana.

Throughout the whole of these mounds the sulphur bearing beds appear to be remarkably uniform both as to structure and the depths at which these beds are found.

At Sulphur Mine the sulphur bearing bed is a spongy porous rock made up mostly of limestones and gypsum, in which the sulphur usually appears to exist in the form of crystals deposited in water, stalactites and crystals along channels in the limestone rock and associated with an enormous amount of hot water carrying free sulphuric acid and great volumes of hydrogen sulphide. At Vinton the sulphur bearing rocks are also porous and full of large cavities. At Spindletop the sulphur occurs in a dolomitic rock carrying oil and sulphur water. These rocks are also porous and full of large cavities carrying hot saline and sulphur water with free sulphuric acid and hydrogen sulphide. At Bryan Heights we find soft porous limestones and gypsum with cavities filled with sulphur crystals. Microscopic thin sheets and small grains of sulphur occur scattered through the gypsum. Throughout this field immense quantities of hot sulphur water, free sulphuric acid and hydrogen sulphide, are met with.

Gypsum forms a very important division of these mounds. This material is found scattered throughout the whole of the Gulf Coastal region, but the massive variety occurs mostly in the mounds. These gypsum deposits are generally of great thickness, sometimes very pure and sometimes changing to beds made up of alternate layers of gypsum, anhydrite, sand, and clay. Of the massive variety may be mentioned the deposits at Humble, where a thickness of nearly five hundred feet of a grayish colored gypsum is found; at High Island 600 feet; at Big Hill in Jefferson County over 1000 feet of grayish colored gypsum carrying grains of salt and sulphur; at Stratton's Ridge 600 feet of a dirty gray colored gypsum with occasional black spots and thin plates and some crystalline to amorphous structure; at Bryan Heights 500 feet. In the Bryan Heights field the gypsum is of a light grayish color, more or less stratified or laminated, and interstratified with sand, sandstone, limestone and large quantities of sulphur, with occasional nodules of barite. It is partly amorphous gypsum and partly selenite. Small blocks of limestone appear scattered through the mass. At Damon Mound the gypsum is over 370 feet thick. Farther west at Piedras Pintas the gypsum has a thickness of over 300 feet and at Loma Blanca in Brooks County the gypsum appears as selenite and is over 900 feet in thickness. This material at Loma Blanca lies in the form of sheets from two to four inches thick, and is broken by large cavities at various depths.

The beds here classed as massive are by no means solid throughout. Many of them are badly broken, and cavities, some of considerable size, occur in every one of these deposits. At Bryan Heights the gypsum has been found to contain numerous cavities of various sizes. Some of these were filled or partly filled with sulphur, others with a black sulphur water having a temperature of 160 degrees, and still others with hydrogen sulphide. Large cavities occur in the gypsum at Pierce Junction, and at Loma Blanca cavities of more than twenty feet in depth were passed through in drilling.

It is impossible to say whether these underground channels are due to acid bearing water finding its way into these deposits and excavating channels through the softer portions of the deposits (these gypsums as a whole are not equally hard) after the beds were laid down, or whether the caverns are due to a

splitting or fracturing on account of the less pliant gypsum being unable to accommodate itself to the surface of the salt after a portion of this easily dissolved salt had been removed. Very little is known about these cavities, except their perpendicular depth, although from efforts to stop them up, they are inferred to be of considerable size.

Limestones appear to be associated with these gypsums to a great extent. At Spindletop, Saratoga, Batson, Bryan Heights and Damon, as well as in most of the other mounds, occur beds of limestone, sometimes porous, often dolomitic and frequently massive. At Damon Mound the gypsum has the appearance of being the altered end of the massive limestone beds found at the southern end of the mound. Two limestone beds having thicknesses of 70 and 650 feet respectively are reported from the southern end, lying between 260 and 1180 feet. Three-quarters of a mile north the gypsum beds are 378 feet and 409 feet thick, with 30 feet of sulphur and sand between.

The line of separation between the limestone and gypsum is an extremely irregular one. In places large blocks of gypsum extend for many feet up into the limestone beds and in others the lime descends into the gypsum. Although the massive beds are here designated as gypsum, they are by no means wholly sulphate of lime. Tests made of cores brought out of a number of wells show them to be a mixture of sulphate and corbonate with the carbonate usually in contact with the sulphate.

Lying at the base of these mounds we have enormous deposits of rock salt. Some of these exceed 2000 feet in thickness. These are not in the amorphous form as is generally stated. In drilling operations the structure of these deposits is never seen but in the salt mines of lower Louisiana there are sometimes opportunities for viewing peculiarities of structure which may help to clear up some of the questions raised regarding the deposition of the salt. In the Myles salt mine it was noticed that on one of the faces the salt showed a peculiar lamination, the various layers being distinctly marked by a black streak. Near the floor of the mine, but in the face of the wall, there appeared a large boulder or concretion of salt. It was of the same material as the laminated structure and the laminae or layers all bent over this concretion giving the whole face of the salt the appearance of having been deposited after the concretion

had fallen down. This structure would indicate that the salt had been deposited in a somewhat steep sided trough and the concretion had fallen from some part of the side. Another condition of deposition shown by this mine is that the salt lies in a somewhat stratified form and when broken down by shooting it breaks in rough slab-like pieces and similarly formed slabs fall from the roof when tested for safety after each shot.

While no evidence of fracture or a cavity was seen in the Myles mine large cavities in the salt occur at Belle Isle, and Lucas reports having found the salt in a crushed condition in the other mounds explored by him.

The upper surface of the salt deposits appear to be somewhat irregular. At Anse La Butte the top of the salt is separated from the main body by several feet of gravel. At South Dayton it comes in contact with a hard limestone. At Dayton the upper portion is mixed with sand and the same condition exists at Barber Hill, some portions of Pierce Junction, and several other localities. In a well drilled at Pierce Junction hot water with small crystals of salt was found lying on the top of and in association with the salt, and at Missouri City the upper portion of the salt was found intermixed with gravel.

In the Rio Bravo well drilled near the top of the dome at Humble, a thin bed of small gravel lay about three feet above the salt. Owing to some peculiarity of this gravel it was impossible to keep it in a sample bottle. A few pebbles placed in a two ounce bottle invariably broke out the bottom and this even when the stopper was out. This peculiarity may have also existed at many of the other mounds, but passed unnoticed owing to the methods of drilling. In no place can the surface of the salt be said to be uniform. It may also be noted that in several of the mounds these salts have been found in the form of sills or stringers, sometimes extending nearly half a mile from the main body of the salt. This condition is known to occur at Anse La Butte, Vinton, and Hoskins Mounds, and probably at many other places.

Age of the Mounds.

Geologically, these mounds are all of the same age. They all belong to the Upper Miocene or Lower Pliocene. Mr. Harris appears to think they are of Cretaceous age, but the actual fold-

ing of Upper Miocene deposits over the summits of the mounds themselves, and the presence of late Pleistocene deposits in the form of red sands and clays covering the surface, would appear to indicate that the culmination of the uplift took place in that period.

In this connection it is interesting to note the close approximations of the elevations of the several mounds, not only as regards their height above the prairie but the top of the sulphur bearing formation in feet.

	Elevation.	Depth to top of Sulphur.	Depth to bottom of known Deposits.	Thickness.
Sulphur Mine	30	505	900	395
Vinton	30	541	940	399
Spindletop	30	740	1080	340
Bryan Heights	35	762	1090	328
Damon	83	171	587	416

Occupying a very wide extent of country we have a series of brackish water, palustrine, and lacustrine deposits consisting mostly of blue clays, clayey shales, marly limestones, coarse grained grayish blue calcareous sandstones, arenaceous limestones, and thin beds of sand. These are known as the Fleming beds and are found on the surface along a belt of country from Alexandria in Louisiana as far west as Navasota and probably a great deal farther under various names and disguises. Toward the south the fauna belonging to these beds show them to occur at Pine Prairie at a depth of 1545 feet, 1550 feet at Anse La Butte, 3000 feet at Edgerly and 3100 feet at Terry. While the shore deposits of the Fleming are mostly blue and greenish clays with great quantities of calcareous nodules, the seaward extension of these deposits are bluish colored shales and clays, bluish to grayish sandstones, blue to gray marly or coarse grained limestones. Of the rock strata the limestone is the more plentiful. Occasional thin beds and small deposits of selenite and amphorous gypsum are seen in well drillings.

While the shore deposits of these Fleming beds are nonbituminous the off shore or seaward extensions are bituminous to a considerable degree. Shows of oil appear in thin beds at various horizons and some producing wells obtain their production from these beds. The large producers along the eastern

side of the Humble and western side of the Sour Lake fields appear to obtain their supplies from sandy shales belonging to a somewhat earlier horizon than what is here called the Fleming beds.

There are some differences between the paleontologists who have examined the faunas found in the different localities embraced in these beds but upon the whole we may consider the age of these Fleming beds to be either late Miocene or early Pliocene. The vertebrate fauna appears to favor the latter.

The very wide distribution of these Fleming beds bring them in very close contact with the mounds. There is not a single mound with which they are not associated. In one or two instances these shales pass over and rest upon the crest of the mound. This is the condition at Saratoga but the shales are much thicker around the edges than on the top. In the other fields the shales lie around the base of the mounds and generally lie tilted high up around the sides of the central core of gypsum and salt and in several places appear to have been pushed aside to permit the salt to extravasate into the shaly deposits. In the Humble field these shales are found lying well up on the gypsum and other mound forming material but not surmounting the same. These shales do not appear on the summit of the mound but seem to thin out toward the edge and thicken as they recede from the mound. These same conditions are found at Sour Lake, Barbers Hill, High Island and other localities. At Spindletop the shales appear to rise toward the mound but disappear somewhere along the sides before reaching the top.

From the conditions in which these shales lie in their relations to the mounds it looks clear that the gypsum, salt and other mound making materials are much younger than the shales.

Not only does the general tilting show this but it has been observed that at many places the salt itself has been found intruding into the shale.

It looks as if we might consider these mounds as being of late Miocene and early Pliocene age.

Origin of the Mounds.

The origin of these mounds has been a subject over which there has been considerable controversy for a long time and many theories have been advanced to account for their origin.

It is not my intention to enter into any discussion regarding these theories but simply to point out the conditions and the causes which may possibly have had something to do with their origin.

It may be assumed that these mounds indicate lines of weakness extending across the country in a course somewhat roughly parallel to the then existing coast line and that that line was marked by small depressions or ponds very like some of our present day depressions or ponds. Into these, thermal spring waters brought a mixture of lime and salt more or less accompanied by hydrogen sulphide or carbon dioxide. These limes and salts were precipitated and as the coast was in a sinking condition the mounds were gradually formed. A cessation of the sinking put an end to the formation of this set of mounds. As the coast again rose no more mounds would be formed, or if formed would be washed away. Another period of depression setting in the old line of weakness would again be the line of springs and to these springs may be ascribed the formation of the second set of domes and as the intervals between the first domes would naturally be the lowest and weakest points within the area the springs with their saline contents would operate in these areas. Cross folding may have had something to do with this condition.

Whether the shales and other materials going to make up the Fleming beds, furnished the material or at least contributed largely to the building of these mounds cannot as yet be definitely determined. These shales carry large quantities of saline and other mineralized waters and probably such waters have something to do with the formation of the mound.

These shales also carry lime in a carbonate form as well as gypsum. While gypsum is more or less scattered throughout the upper portion of the beds it is also found lying in long rather narrow thin sheets at considerable depth and mostly in association with the mound. Thus in the Golden Flow well west of Spindletop gypsum was found lying below 2900 feet and on the northeastern side of Hoskins Mound a well was finished in 45 feet of gypsum and sulphur at 1791 feet. At Pierce Junction a well found a mixture of gypsum and Gumbo at 2170 feet and finished in gypsum at 2700 feet. These conditions exist at Anse La Butte, Vinton, Dayton, Barbers Hill and some other mounds

and lead to the idea that the gypsum and salt forming the cores of the various mounds do not descend very far below the base of these shales, if below them at all. It looks from the condition as we now have them that these gypsums may form a wide rather straggling base upon which the mound itself has been built. This base although somewhat widely spread does not appear to be very thick at any place but having a saucer like shape is the thickest toward the center, or in the neighborhood of the dome.

Lime in the form of carbonate is plentifully scattered throughout these shales and in many places considerable deposits of iron pyrites occur. Large volumes of hydrogen sulphide also occur in the sands associated with these shales. There is therefore sufficient material within the shales themselves to account for the formation of the salt domes and their accompanying oils.

From the structure of the gypsum found in association with and overlying the salt, especially where sulphur occurs, it looks as if this gypsum was originally deposited as lime and afterwards transformed to gypsum. Under this transformation the dome would obtain an increased elevation of a good many feet. Afterwards with aid of carbonaceous matter the hydrogen sulphide extracted the sulphur and set in another transformation from gypsum to carbonate of lime, but in doing so the whole of the gypsum has not yet been converted. Nothwithstanding this movement the mounds still retain their altitude. The material classed as gypsum carries carbonate of lime, streaks of anhydrite, considerable salt, both in streaks or thin beds and grains and is very badly broken by large cavities.

Many of these reactions took place in Quaternary times and are possibly going on yet as most of the mounds are overlain by 600 to 800 feet of ucuaternary deposits with the gypsum extending up into these deposits.

In dealing with the origin of the mounds it is well to consider the association of the gypsum and salt as both are very closely associated; but the two deposits occupy positions the reverse of what these two normally ought to occupy; that is, the salt underlies the gypsum. The question is, was the salt laid down first or did the two come together? It looks, how-

ever, as if a portion of the salt was laid down first in position and was partly in solution when the gypsum began to be deposited. After that, the two apparently reached the forming mound at the same time but the salt was very much in excess of the lime. This may be seen in the formation of what is known as the "trembling marshes" at High Island. In these carbonate of lime and salt is coming together. At Big Hill in Jefferson County, although no salt deposits have been seen, salt crystals enough to give the gypsum taste is found in the gypsum at a depth of 1300 or at least 100 feet above the bottom of the drill hole. At Bryan Heights small particles and stringers of salt of irregular form also appear at some distance above the main body of the salt. These same conditions exist at other mounds and at Pierce Junction a hot saturated solution carrying crystals of salt was found between the bottom of the gypsum and top of the solid salt. In drilling at Saratoga I found water having a temperature of 180° F. carrying carbonate of lime and salt in solution with the salt greatly in excess of the lime, although we found over 100 feet of lime in another well about 600 feet away at a corresponding depth. When chilled the lime and salt settled as an intermixture.

It is a general condition that salts in solution will be deposited in the order of their solubilities, that is the least soluble will be deposited first. Throughout these salt domes the reverse is the condition found. The salt lies at the bottom and the gypsum on top. Not only is this the case in the mound but everywhere else throughout the coast country where the two are found in association, the salt is below the gypsum. Under these conditions and as both the salt and lime are of secondary origin there must have been some other cause affecting these minerals than the simple one of solubility. Probably Van't Hoff's view that where more than one salt appears in a solution these salts react upon each other and change the order of their deposition or, that in the case of any one being in excess, that salt will be the first to go down and will continue depositing until an equilibrium has been established, will apply to the deposits. Salt is decidedly in excess in every one of the mounds as it is known to be over 2000 feet in some of them and if Van't Hoff's rule should apply then the salt should be found beneath the gypsum.

The gypsum deposits overlying the rock salt were very probably laid down on carbonate lime and probably owe their position to the small percentages found in the original solutions as compared with the salt. These leposits carry anhydrite and lime in varying proportions and unde. varying conditions. Many of the blocks and small pieces of lime show effects of corrosion. Limestone is plentifully scattered throughout the Tertiary deposits. Scarcely a well has been drilled throughout the coast country that does not show limestone, some of them as much as 100 feet, but mostly these limestones are from five to ten or more feet in thickness.

Carbonate of lime goes into solution when associated with carbon dioxide in alkaline solutions. An examination of the analyses of the soils, sub-soils, clay and waters both of the rivers and deep wells show the presence of alkalies in considerable quantity. The hydrogen sulphide necessary to reduce this calcium carbonate to calcium sulphate exists throughout these various geological divisions involved, in enormous volumes. Free sulphuric acid is also plentiful. There is, therefore, a strong probability that the gypsum was brought into its position at about the same time as the salt in the form of lime carbonate and was afterwards transformed to gypsum by the action of sulphuric acid or hydrogen sulphide and oxygen. The lime was obtained from the leaching of the various beds from the upper Cretaceous to the Miocene and probably Pliocene.

Under the transformation of the lime to gypsum the dome would obtain an increased elevation of a good many feet.

In an article in Popular Science Monthly for Ferbuary, 1913, Harris expresses the idea that during Permian times immense bodies of salt were laid down; that the salts coming in contact with surface and other waters gradually dissolved, sinking into the earth, became hot and after a long period of percolation eventually found an outlet in the later Tertiaries of the Gulf. This is practically lateral secretion although it is not necessary to go back to Permian times and it may be noted that no Permian whatever is known in any region from which these saline waters might possibly have come. There is an abundance of saline matter including enormous quantities of salt water everywhere throughout the Gulf Tertiaries to account for the salt found in these mounds, enormous as it is.

Nor is it necessary to assume that these solutions became hot from the friction due to percolation. As a matter of fact they did not, as salt waters found in the wells drilled at localities away from the mounds show only normal temperatures in keeping with their depth. The only hot waters found occur within the vicinity of the domes and the heat generated by the chemical reactions set up in the transformation of the lime to gypsum will more than account for the heat of the waters found in the vicinity of the dome.

The general condition of the dome forming material in Louisiana and Texas so far as known appears to be that they are associated with sedimentary deposits and this led Stutzer in dealing with the sulphur deposits to assert that they are formed contemporaneously with the country rock in shallow basins or depressions.

If this be true then we may have the key to the origin of these mounds or domes. Let us suppose that these deposits were laid down in Miocene times, and we know that most of our Miocene deposits carry very large percentages of salt, carbonate of lime and organic remains. There would in all probability be irregularities in the deposition of the materials, lime being deposited in some places and carbonaceous shales and clays in others. There would also be more or less iron in the form of carbonate amongst these clays and shales as well as hydrogen derived from the decaying vegetable matter enclosed in the clay. This hydrogen coming in contact with the iron would form sulphides and these at a later stage would give rise to sulphuric acid and hydrogen sulphide. The sulphuric acid having a strong affinity for the lime deposited in the depressions or basins would change this to anhydrite and gypsum, increasing the bulk of the material nearlly 34%. This, considering the quantity of gypsum found would in itself give rise to a considerable elevation.

Another point we may reasonably suppose is that the deposits carry a great many times more the quantity of saline matter than calcic matter and this, as well as the more ready solubility of the salt would give the salt a greater preponderance in the percolating solutions and under these conditions it is very probable a large proportion of salt had reached the depression or basin in which it was deposited before the less soluble lime carbonate began to more. Evidently the two ingredients reached

the basin together in unequal proportions and then due to this inequality the lime remained longer in solution than the salt. Very little lime occurs intermingled with the salt but considerable salt remains in the lime or its gypsum condition. This no doubt accounts for the presence of the gypsum above the salt.

Objection might be offered to this lateral secretion on account of the presence of so much water and its disposal after arriving at the basin, but it must be considered that this water in its passage through the saline bearing beds would be constantly coming in contact with saline material and it may have reached the end in a highly charged condition, in fact as a saturated solution of salt intermingled with a little lime. There is also this condition favorable to the theory of lateral secretion, that is the total absence of potassium salts.

Taking everything into consideration it looks to me as if these salt domes are comparatively modern. There is no necessity to seek for the origin of the dome forming material in Paleozoic times as there is an abundance of the necessary material present in the beds belonging to the later Tertiaries and these materials were accumulated in depressions or basins formed along the lines of weakness across the region. These mounds apparently began to be formed during Miocene times at a period when the shore line was sinking. These solutions with their depositions of salt and lime approximately kept pace with the lowering of the region sometimes in excess and at other times falling behind. This continued at least to the time of the deposition of the Beaumont clays in Pleistocene times when the movements apparently ceased long enough to permit of these clays being laid down as a smooth sheet. The transformation from lime to gypsum may have reached its culmination at a later date and the increased bulk of the gypsum may possibly have been the cause of the elevation of the dome.

I am not offering this as a solution of the question but simply as a suggestion.

THE HUMBLE (TEXAS) OIL FIELD

By Alexander Deussen, *Houston, Texas*

(Tulsa meeting, February, 1917.)

Introduction.

The Humble Oil Field is one of the most important of the salt dome fields in the Texas-Louisiana Coastal Plain. It is located in Harris County, Texas, about 18 miles northeast of Houston and 1½ to 2 miles east of the town of Humble on the Houston, East and West Texas Railway.

History.

Following the discovery of the Spindletop field at Beaumont in January, 1901, attention was attracted to many of the localities in the coast country where seepages of oil and gas were known to exist, and these districts were actively prospected for oil.

Escaping gas had been known in the vicinity of Humble for many years. In the fall of 1902 George Hart tried to drill a well in the west part of the present field but was stopped by a "blow out." C. E. Barrett in 1904 drilled several wells in that part of the field known as Moonshine Hill, but most of these were ruined by "blow outs." In October of this same year the Higgins Oil & Fuel Company brought in a large gas well about one-half mile southeast of the Barrett wells.

The first successful oil well was the Beatty No. 2, completed January 7, 1905. For some days this well yielded 8,500 barrels per day. Other producing wells followed in rapid succession. Some of these yielded more than 10,000 barrels daily. Before March 1st., the daily production was nearly 90,000 barrels, and within three months after the completion of the discovery well the field had produced 3,000,000 barrels of oil.

Previous to March 3rd little salt water was observed. On that day water began to appear. In 10 days the production fell from nearly 90,000 barrels to less than 25,000 barrels. Partly

by the bringing in of new wells on the east side and partly by the renewal of flow from the wells which had been "drowned out," the field recovered its former production so that the yield in April was nearly 2,000,000 barrels. Beatty No. 2, which stopped flowing on the advent of salt water, began again to flow, and produced 4,800 barrels in one day. The production of the field soon began to decrease again, and in November 1905 it was but little more than 20,000 barrels per day.

In the interval between 1905 and 1913 activity was confined to the exploitation of the cap-rock area (See Fig. 1.), the limits of which were ascertained shortly after the discovery of the field. In this district the wells averaged 1100 to 1200 feet in depth. The production during this time, following the flush production accompanying discovery, averaged approximately 2,000,000 barrels per year.

Following the exhaustion of the old field at Sour Lake deeper drilling was attempted around the sides of this field, and highly productive sands were discovered at greater depths. A similar trial was made at Humble.

Although the lower sands adjacent to the cap-rock area had been tested in certain parts of the field with indifferent success in previous years, consistent efforts to develop them were not undertaken until 1914. These efforts were made after the successful completion in November 1913 of Well No. 11 Carroll of the Producers Oil Company, on the east side of the pool and in a new and deep body of sand (See Fig. 1.), the well being rated at 10,000 barrels initial production and the oil obtained from a depth of about 2,700 feet. The discovery of this deep sand was followed by an active period of development, during which the production was increased to 10,102,800 barrels in 1916.

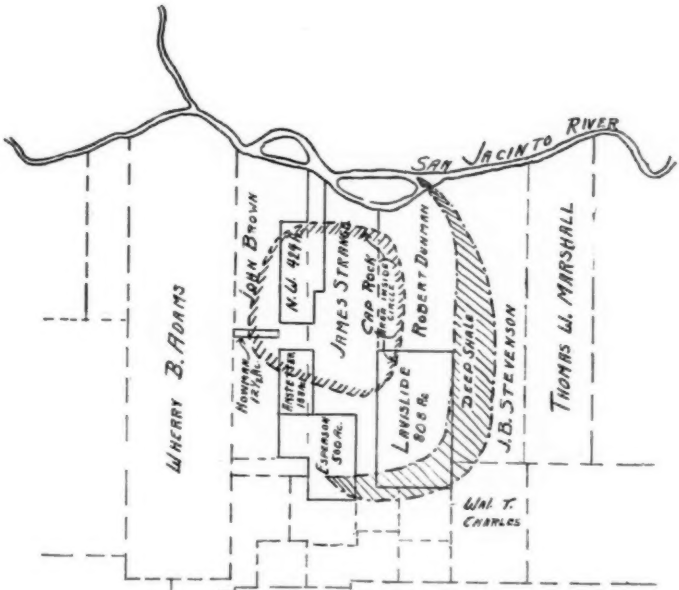


Fig I.

Map Showing Location of the Cap-Rock and Deep Sands producing Areas at Humble.

*Production Statistics.**

The production of the field by years is as follows:

Production of the Humble Field.

Year	Barrels.
1905	15,594,310
1906	3,571,445
1907	2,929,640
1908	3,778,521
1909	3,237,060
1910	2,495,511
1911	2,426,220
1912	1,829,923
1913	1,504,880
1914	2,799,458
1915	11,042,570
1916	10,102,800
TOTAL	61,312,338

Geology.

The Humble field, like the other fields of the Texas-Louisiana Coastal Plain, lies in that belt of country, 50 to 70 miles wide, bordering the coast, and characterized by extremely flat topography. The oil fields themselves are usually associated with small hills or elevations, which are rarely more than two miles in diameter and appear on the plain in places.

The center of the Humble field is roughly marked by Moonshine Hill, a low elongated elevation rising barely more than 20 feet above the surrounding plain. To the south, east and west is a gradual, even, and gentle slope. On the north, the original surface of the plain has been destroyed by the San Jacinto River, resulting in the formation of a flat or a terrace lying some 20 to 40 feet below the level of the adjacent plain.

At places in the field small low mounds, popularly called "gas mounds", rarely more than 30 feet in diameter and 5 feet

*In barrels of 42 gallons each; figures from U. S. Geological Survey and the Fuel Oil Journal.

high at the center, appear; and in spots small marshes 100 to 200 feet in diameter are also present.

The salt dome fields, of which Humble is a typical example, are characterized by the presence of a massive core of rock salt intruded into the adjacent and surrounding strata, resulting in the tilting of these later to a high angle around the sides. There is usually on top of the salt mass a sheet of coarsely crystalline, porous, and cavernous limestone or dolomite, deposited at a time subsequent to the intrusion of the salt, and commonly called cap-rock. In a number of cases this cap-rock is filled with oil, and forms the productive horizon. It is usually the rule that a mass of gypsum occurs between the limestone and the salt. Sulphur in the form of stringers, crystals, impregnations, and veins is usually found in or near the limestone. Above these characteristic dome materials are unconsolidated sands, clays, gumbos, and shales similar to those found elsewhere in the Coastal Plain of Texas away from the domes, but these beds in and around the domes also contain strings of pyrite in places, concretions of lime, and in spots hard sandstone layers.

At Humble the cap-rock is rudely circular in shape and is about 1½ miles in diameter. Its location is indicated on Fig. 1, It lies practically horizontal, and is encountered at depths varying from 1100 to 1200 feet. It is a coarsely crystalline, porous, and cavernous limestone of secondary origin, and at the time of discovery was saturated with oil under a heavy gas pressure. There is no uniformity in the texture of the rock, which varies from fine-grained, compact limestone to coarse, porous limestone, or a cavernous limestone. This variation in texture is responsible for the differences in the capacities and behavior of wells side by side. Originally, when the cavernous spots were penetrated, these produced large gushing wells, but these held up for only a short time. The coarse porous rock produced smaller but longer lived wells, and the fine grained rock produced gas wells which blew out with tremendous force. Since the cap-rock field has been thoroughly explored, the general location of the areas of cavernous rock, coarse rock, and fine rock are fairly well known, and can be roughly delimited on a large scale map. The variation, however, is so erratic that no definite prognostication can be made in advance of the drill. One well

may be in a fine rock and another, drilling 50 or 30 feet from it, may enter cavernous rock.

Following the discovery of the field numerous wells were drilled in the cap-rock area and great quantities of oil were removed. Its place was taken by salt water which entered from strata on the sides of the dome or was admitted to the rock from strata above where the wells were not properly cased and cemented. Inasmuch as the oil is most easily removed from the cavernous rock, these wells were the first to go to water and fail. In the finer grained rock the oil resisted the encroachment of the water. and it is these spots and the upper portions of the rock which are producing the oil today.

Some of the sands above the cap-rock contain oil in more or less quantity. These are usually very local and limited in extent. In the early days these sands were usually ignored in the attempt to reach the cap-rock. In the later years small wells have been secured in these upper sands, and it is probable that with the exhaustion of the cap-rock, these upper sands will be more extensively developed. It may be expected that a considerable amount of oil can be recovered from this source.

On the west side of the cap-rock district a small body of sand has been found which dove-tails into the cap-rock. This sand was not developed in the early history of the field but during the last two years has been actively exploited, and a large production has been secured therefrom. It is possible that similar sands may surround the cap-rock in other parts of the field.

Some of the earlier wells in the cap-rock made as high as 12,000 barrels of oil daily. As previously indicated such wells were short lived, some not flowing more than two or three days, then dwindling to 200 or 300 barrels in the course of four or five weeks, and then failing altogether. Others which drew oil from tighter rock made a small initial production, possibly not over 150 barrels, but have been pumping continuously for over ten years and are still making 15 to 20 barrels a day. As a general rule any well finished in the cap-rock area at the present time rarely makes more than 20 or 30 barrels, but with the present price of oil—some of which is contracted at $1.30 per

barrel—such wells may be relatively more profitable than the larger wells in the early history of the field when oil had to be sold at 16c per barrel.

Beneath the cap-rock and gypsum, which varies in thickness from 50 to 250 feet, rock salt occurs, as demonstrated by a number of wells which have been drilled into it.

A number of years ago the Producers Oil Company drilled well No. 174, Mason, in the cap-rock district and entered salt at 1406 feet. The hole was abandoned in salt at 4380 feet. In July 1916 this same company drilled No. 17 on Block 29, of the Wheeler-Pickens sub-division. Salt water was encountered in a sand at 2001 feet and rock salt was entered at 2342 feet. The well was abandoned in salt at 5410 feet, the drill having passed through 3068 feet of solid salt.

The form of the salt plug at Humble is that of a truncated cone, flat on top and covered by the cap-rock. The east and south sides of the plug between the edge of the cap-rock and a circular line about one mile distant have a slope of 15 to 40 degrees from the horizontal (See Fig. 2.). No data are available showing the dip of the salt surface beyond this line, but the drilling thus far done seems to indicate a very steep and probably vertical dip in this portion. The dip on the west seems to be much steeper than on the east.

The salt core on the east, south, west and probably north sides are overlain by a black shale 200 to 400 or more feet in thickness and soaked with oil of a light gravity. This shale is usually compact, but in places sandy streaks occur. It appears that the shale is the fountain which has fed the oil to the cap-rock and to the sands to be presently described.

Lying against the black shale on the east and south there is a bed of generally coarse sand between the 2700 and 3500 foot levels. This sand, which is in places as much as 200 feet in thickness, also dips at a high angle away from the center of the dome, conforming in general to the dip of the black shale. Where this sand lies in contact with the oil-bearing shale, the oil has invaded the sand, and formed a prolific pool. Further down the dip, the oil gives way to water. There is, therefore, a narrow belt of oil bearing sand in the shape of a crescent encircling the cap-rock and lying between the 2700 and 3500 foot level (See Fig. 1.). In this sand, which was discovered in 1914,

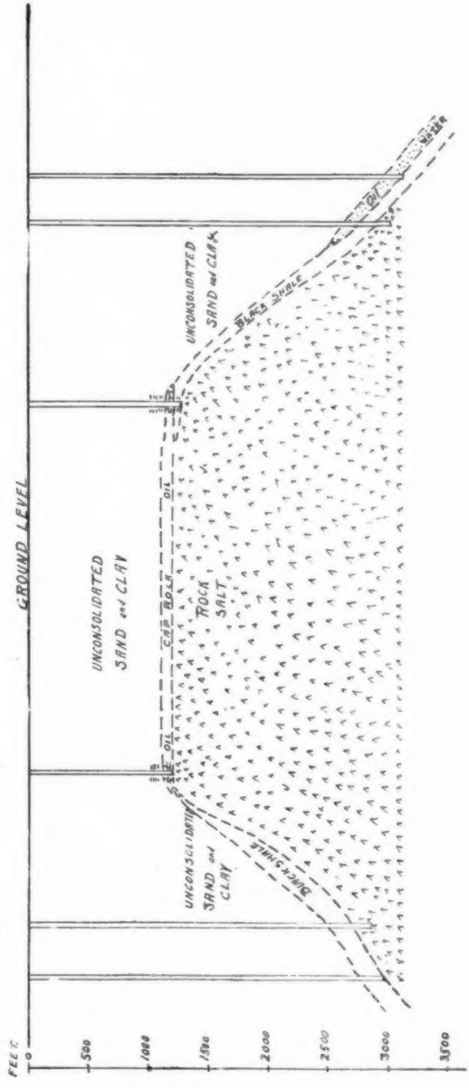


FIG. II.

GEOLOGIC SECTION ACROSS HUMBLE FIELD.

Northwest to Southeast • NW ⟶ SE

Horizontal Scale — 1 In = 800 Ft.

many large wells with initial productions as high as 15,000 barrels were finished in 1915 and the early part of 1916. The coarse nature of the sand has been favorable to large production.

In the area intermediate between the deep sand and the cap-rock smaller and more local bodies of sand are known to lie against the black oil-bearing shale, and the shale itself in spots contains lenses of sand and sandy shale. Whenever the drill enters such a sand a well can be obtained, but owing to the limited extent of such beds and the generally fine texture the wells are not large. On the other hand they are longer lived. Such sands supply the wells on the north part of the Hermann tract leased to the Invincible Oil Company, and the wells on the Jack Rose and Henryetta leases on the Landslide. It will probably be true that in this area some coarse sands will be found in spots which will make fairly large wells, but the extent of such sands will probably be limited.

Most of the area between the deep sand and cap-rock has not been tested to date. It is probably true that the main supply of oil which will be secured at Humble in the next ten years will come from this part of the field.

An interesting variation in the character of the oil obtained in the different portions of the field has been noted. The cap-rock oil is a heavy black oil testing 21° B. with a high content of sulphur; it is valuable chiefly for fuel. The deep sand oil is a lighter green oil testing 24° B. It is a high grade of lubricating oil, the merit of which is recognized by the refineries. The following is an analysis of the oil.*

Analysis of oil from Blaffer & Farish Well No. 4,
Paraffin 40 acre lease at Humble, Texas.*

		Gravity	Flash	Fire	Viscosity
Kerosene	5%	39.0			
Gas Oil	30%	28.1			
Spindle Oil	17%	22.1	330	380	100@ 70
Motor Oil	13%	19.7	425	490	2300@ 70
Cylinder	25%	19.2	470	550	135@210
Asphalt	5%				

The oil from the fine textured sand in the area between the cap-rock and the deep sand, and in spots in the deep sand

*Analysis furnished through the courtesy of Blaffer & Farish.

area, is a light green oil testing 37° to 40° B., and suited for the manufacture of gasoline. Thus far only a small quantity of this oil has been produced. A small refinery in the field is now utilizing this oil for making gasoline. The following is an analysis of the oil*

Analysis of oil from Blaffer & Farish Well No. 10
Paraffin 40-acre lease at Humble, Texas.*

		Gravity	Flash	Fire	Viscosity
Gasoline	25%	58.8	End point 315.90% off 300		
Kerosene	29%	43.8			
300 Oil	13%	37.8			
Spindle Oil	8½%	33.2	325	360	62@70
Motor Oil	20%	27.2	410	470	260@70
Asphalt	2%				
Wax	1½% Approximately				

Gravity of Crude oil 39.2° Baume.

To afford some idea of the nature of the formations penetrated in different portions of this field two logs are added, one in the cap-rock area and one in the deep sand section:

Log of Well No. 1, Martin on the Gulf Coast Oil Corporation lease in the west part of the cap-rock district, at Humble, Texas.

Bed:	Thickness Ft. In.	Depth: Ft. In.
Sand and Clay	30	30
Sand	300	330
Gumbo	70	400
Rock (water flow)	10	410
Hard Gumbo	210	620
Shale	90	710
Shale and Boulder	20	730
Gumbo	75	805
Shale (showing oil)	105	910
Gumbo	30	940
Shale	40	980
Gumbo	20	1000

*Analysis furnished through the courtesy of Blaffer & Farish.

Oil sand (very fine showing but little oil)	35		1035	
Hard oil rock (cap-rock)	40		1075	

Log of Blaffer Farish Well No. 2, on Paraffin 40-acre leas eat Humble, Texas.
(Completed October 30, 1915.)

Bed:	Thickness Ft.	In.	Depth: Ft.	In.
Soil	5		5	
Clay	31		36	
Sand	10		46	
Clay	24		70	
Sand	10		80	
Clay	13		93	
Sand	47		140	
Gumbo	24		164	
Hard Sand	47		211	
Sand and Boulders	12		223	
Gumbo	68		291	
Sand	43		334	
Gumbo	42		376	
Sand	21		397	
Gumbo	32		429	
Sand	28		457	
Gumbo	8		465	
Sand	18		483	
Sand and Boulders	3		486	
Gumbo	5		491	
Sand and Boulders	23		514	
Rock	6		520	
Sand	20		540	
Sand and Boulders	43		583	
Gumbo	10		593	
Shale	12		605	
Sand and Boulders	43		648	
Sand	21		669	
Gumbo	62	8	731	8
Rock	3		734	8

Sand ________________	24	2	759	
Gumbo ______________	18		777	
Shale and Boulders ____	15		792	
Gumbo ______________	49		841	
Rock ________________	3		844	
Gumbo ______________	30		874	
Rock ________________	1	6	875	6
Shale and Boulders _____	9	4	885	
Gumbo ______________	99		984	
Sand and Boulders _____	51		1035	
Rock ________________	2		1037	
Gumbo ______________	21		1058	
Shale and Boulders _____	87		1145	
Hard Sandy Shale _____	64		1209	
Gumbo ______________	33		1242	
Rock ________________	4		1246	
Sand ________________	7		1253	
Rock ________________	1	6	1254	6
Gumbo ______________	10		1264	6
Sand and Boulders _____	21	4	1286	
Gumbo ______________	76		1362	
Hard Rock Shale ______	10		1372	
Gumbo ______________	77		1449	
Gumbo and Gyp _______	21		1470	
Sand ________________	26		1496	
Gumbo ______________	56		1552	
Hard Sand and Boulders	52		1604	
Gumbo ______________	19		1623	
Sand ________________	10		1633	
Gumbo ______________	201		1834	
Sandy Shale __________	29		1863	
Rock ________________	1	6	1864	6
Gumbo ______________	25	4	1890	
Shale ________________	15		1905	
Gumbo ______________	133		2038	
Hard Sand and Boulders	8		2046	
Rock ________________	2	6	2048	6
Rocky Shale __________	33	4	2082	
Gumbo ______________	13		2095	
Gyp _________________	5		2100	

Gumbo and Gyp	33		2133	
Hard Shale	28		2161	
Rock	2		2163	
Rocky Shale	18		2181	
Gumbo and Gyp	33		2214	
Rocky Shale	16		2230	
Gumbo	115		2345	
Mixed Shale	25		2370	
Soft Water Sand	101		2471	
Gumbo	20		2491	
Gummy Shale	13	6	2504	6
Rock	14		2518	6
Gumbo	36	4	2555	
Soft Rock	1	6	2556	6
Gummy Shale	19	4	2576	
Shale and Boulders, showing gas	10		2586	
Hard Sand, showing oil	4		2590	
Gummy Shale	6		2596	
Hard Sand, showing oil	4		2600	
Gummy Shale	17		2617	
Soft Sandy Shale, showing oil	34		2651	
Gumbo	39		2690	
Shale	5		2695	
Gumbo	5		2700	
Hard Shale	5		2705	
Gumbo	5		2710	
Soft Sand, showing oil	5		2715	
Hard Sand	54		2769	
Hard Shale	5		2774	
Gumbo	81		2855	
Sand, showing oil	8		2863	
Hard Shale	8		2871	
Soft Sand, showing oil	48		2919	
Blue Shale	6		2925	

Steel Line Measurement Shows 2920 Feet.

Set 12 Joints of 10" in Gumbo at 234'.

Set 118 Joints and 10' of 6", Nipple in Gumbo at 2527.

Set 8 *Joints of Strainer and* 17 *Joints of Blank Pipe as follows*:

4—Joints strainer on bottom.
3—Joints blank pipe
3—Joints strainer
1—Joint strainer at 2630′ to 2652′.

Age of the Formation

The unconsolidated clays, gumbos, and sands above the cap-rock belong to the Lissie formation which is of early Pleistocene Age. The preponderance of evidence indicates that the so-called "Black Shale", which lies directly on top of the salt core around the sides and in spots between the cap-rock and the salt core, belongs to the Yegua formation of late Claiborne Age, although Dumble is inclined to refer the same to the Fleming of Miocene Age. The productive "deep sands" between the 2700 ft. and 3400 ft. levels are apparently referrable to the Catahoula-Fayette sandstone series of Jackson and Oligocene Age. This correlation is based upon the following criteria:

From a clay and shale at a depth of 2500 ft. in the Blaffer-Farish Well No. 20 on the Paraffin 40 acre lease on the south side of the field, the writer secured a number of fossils. This clay and shale lie only a short distance above the productive oil sand which supplies the deep wells on this lease. The specimens were submitted to Cooke, Bassler, Berry and Hussakof. Bassler reported as follows:

> "The species is a *Metra-rabdotos* which hitherto I have seen only in the Caloosahatchee River Fauna. Another species of this genus is very characteristic of the Vicksburgian but the one sent is certainly the Pliocene form."

In a subsequent letter he advises as follows:

> "The specimen of Bryozoan that you sent is either Pliocene or Vicksburgian, and since all the other data make the age apparently Oligocene, I think it would not be stretching a point to say that the Bryozoan is also of this age. As I said before, this genus is represented in America only at these two horizons. The species are very similar and it is probable that your specimens which are

poor might just as well represent the Oligocene form . . . .
Cooke reported in regard to the molluscs as follows:

"I have not been able to identify the fragments, chiefly *Pecten*, from 2500 ft. in Blaffer-Farish well No. 20, at Humble, Texas, they appear to be middle or late Tertiary, apparently not Eocene and probably not Miocene, but may be Oligocene."

To date no report has been received from Hussakof on the shark teeth of this collection, and it may be that when these teeth are studied some additional evidence on the age of this horizon will be available.

The studies of Bassler and Cooke seem to point with a fair degree of certainty to the Oligocene Age of this fossil bearing bed, which is immediately above the productive oil sand in this particular well.

The "Black Shale" occurs, of course, below these oil sands in this part of the field and necessarily would be older than the fossil bearing series just described. It may be that this "Black Shale" is also a part of the Oligocene, but inasmuch as the Yegua is a well known gas and oil bearing horizon and occurs immediately below the Fayette sandstones of Jackson age on the outcrop, it seems to be plausible that this shale is a part of the Yegua and the source from which the oil has been delivered to the sands under the influence of the salt dome structure.

Aside from this evidence reference of this "Black Shale" at a depth of 3500 feet to the Fleming of Miocene Age, would imply a dip of the Miocene beds of approximately 70 to 80 feet to the mile, which is far in excess of the known dip of these beds. The average dip of those Miocene strata is approximately 35 to 40 feet to the mile and the figure of 70 to 80 feet is calculated without assuming any uplift of these beds around this dome, a condition which has most certainly occurred. On purely structural grounds therefore the reference of the "Black Shale" to the Fleming would be doubtful.

The salt, gypsum, sulphur, and cap-rock are purely secondary, probably deposited in the order named.

As previously indicated the sand series occurs only below the 2700 feet level on the northeast and south sides of the dome, and is lacking in the interval between the cap-rock level at 1200 feet and the 2700 feet level. Here the "Black Shale" is capped by a series of pink, green, and blue shales and gumbos, the age of which has not yet been definitely determined. These may belong to the Miocene or early Pliocene, but the reference is doubtful. The condition that seems to have occurred is that in the intrusion of the salt core, the "Black Shale" (Yegua formation) has been bowed upwards and thrust through the over lying Catahoula-Fayette sandstone series, a fault marking the present contact zone between this series and the underlying "Black Shale." The subsequent burial of this structure by the impervious clays, gumbos and shales of Miocene or late Pliocene age has served to make these ruptured sands the prolific oil reservoir that they are.

A number of deep tests have been drilled on the west side of the dome in the hope of encountering the same series of sands on this side, but thus far these tests have not been successful. The oil-soaked "Black Shale" is present at the usual depth, but the sand series has not yet been located and it is somewhat doubtful if it is present at all, although it may lie at a considerable greater depth a little further to the west.

Age of the Dome

The inner belt of coastal domes occurring in Freestone, Anderson, Smith and Van Zant counties were clearly formed in late Cretaceous or early Tertiary time as is evidenced very clearly in the case of the Keechi dome of Anderson County where the Wilcox beds of the Eocene rest unconformably on the Navarro beds of the upper Cretaceous, the Midway being absent.

The Humble dome and probably the other domes in southeast Texas are clearly of later age. Assuming the "deep sand" to be of Jackson or Oligocene age and the "Black Shale" of late Claiborne age, the deformation must have occurred at some time subsequent to the deposition of these formations. It is probable that the dome was formed during the Miocene time or in the interval between the Oligocene and the Miocene. This interval was marked by a land epoch in this part of the coast,

a pronounced unconformity occurring between the Miocene and Oligocene in east Texas, and between the Miocene and Eocene in southwest Texas. This interval and period is known to have been characterized by volcanic activity and faulting, the well known Balcones fault for example being formed at this time. It is probable therefore that this dome either appeared as a peak on the Coastal Plain during Miocene and Pliocene time or as an island in the sea during this same period. This peak or island was subsequently submerged and buried beneath Pleistocene deposits in the Pleistocene Sea. That later movements have occurred since the initial movement is indicated by the slight deformation at present visible at the surface, though these deformations may possibly be due to the growth of the cap-rock or to gas pressure.

MISCELLANEOUS FEATURES

Independence Among Wells

The variable nature of the cap-rock has been previously indicated. Owing to this feature the results obtained in adjacent wells are not uniform. At the present time one well, in drilling into cap-rock may make a water well; another 30 feet from it may make a 40 barrel pumper; another may make a gas well. In general, however in certain districts of the cap-rock area small pumping wells can be completed with more or less success.

Similar conditions obtain to a more or less extent in the deep sand section. The sand itself is by no means uniform in thickness or in composition. It is also in places cemented by lime into hard compact rock. No two wells, therefore, even if placed close together, penetrate exactly the same series of beds. In consequence, likewise, there is a great variation in the capacity and nature of wells close to each other. One drawing from a coarse sand may make a 10,000 barrel gusher; another 50 feet from it, drawing from a tight hard sand may make only a 400 barrel pumper. In places in the deep sand gas wells will be found. To a certain extent these discrepancies are due to drilling; a slight difference in the depth at which casing is set or the well stopped, or the packer placed, may make a large difference in the yield of wells side by side. In general it is true that differences in the nature of the sand at different spots will cause great differences in the character of the wells.

Difficulty in Finishing Sand Wells.

In the deep sand section, there is no persistent sand above the oil sand which can be definitely recognized. Likewise, some of the sands above the oil contain water, and it is therefore extremely difficult for the driller to know exactly where to set his casing so as to shut off the water, or if the casing is set above the water, to know where to place the packer so as to exclude the water, and where to place his screen so as to take in the oil sand. A considerable hazard is always involved in completing a sand well, especially if the well is some distance from tested territory or is drilling in new sands. The completion of a well in the best manner possible is, therefore, to a certain extent largely a matter of chance; water may have been admitted to the well; not all of the oil sand may have been screened in; the well may have been drilled too deep or not deep enough.

Methods of Drilling

The hydraulic rotary system is exclusively used in the drilling of the wells. That system enables a well to be drilled in a minimum length of time and with a small amount of casing. Wells 3500 feet deep if no bad luck supervenes, can be made in the course of three to five weeks.

In the deep sand section at Humble, it is customary to set 10-inch casing from the surface to the 200 or 300 foot level. No additional casing is then set until the 2600 foot level is reached, more or less depending on the depths of the oil sand in the locality being tested. From the surface to this depth 6-inch casing is set in gumbo. This excludes such water, gas, or oil as may be in the sands above the casing point. The attempt is usually made to set the 6 inch casing as close as possible to the top of the oil sand in order to exclude the water above, but inasmuch as it is difficult to detect the nature of the formation being drilled through when there is 1500 to 2000 feet of open or uncased hole, the foreman prefers to set his casing some distance above the point where the oil sand is believed to be. This is done that there may be no danger of passing through the oil sand, and cutting it off with the casing. By so doing, however, water is often admitted to the well from a point above the oil sand and below the casing point. After the 6 inch is set

the sand is drilled into, the formations being closely watched during this stage of the operations. If the foreman has reason to believe no water will enter the well from above the oil sand, he sets in the bottom of the hole a number of joints of screen or strainer, which is either connected with a line pipe extending from the top of the screen to the surface, or connected by pipe from the top of the screen to the bottom of the 6 inch casing, into which it is sealed or connected by a packer.

If water is coming into the well from above the oil sand and below the casing point, it is customary to set a packer below the sand believed to be yielding the water. The packer prevents the passage of any liquid up or down on the outside of the pipe. The top of the packer is either connected by tubing to the surface, or is connected by pipe to the bottom of the 6 inch casing.

In the cap-rock area, the wells are drilled with rotary tools to the top of the cap-rock. A standard rig is then built and the rock is drilled into with cable tools. The change from the rotary to the cable system is required because of the hardness of the cap-rock, which cannot be successfully penetrated by the rotary. Casing is usually set on top of the rock or in a gumbo above the cap. The hole in the rock stands open, no strainer being used.

Cost of Wells

The cost of wells in the deep sand section varies from \$3.50 to \$6.00 per foot—this includes drilling and the cost of casing. Under favorable conditions and without accident a 3000 foot well can sometimes be completed for \$10,000 or less, but with the mishaps that usually accompany drilling in the southern fields the cost is very often \$15,000 or more.

Wells in the cap-rock area can be finished much cheaper—the cost of drilling and casing varying from \$2.00 to \$3.00 per foot. These wells can be completed and equipped at costs ranging from \$3,000 to \$5,000.

Markets and Pipe Lines

There are four pipe lines into Humble at the present time. They include:—

Texas Company line, which delivers oil to the Texas Company refinery at Port Arthur;

Gulf Pipe Line, which delivers oil to the Gulf Refinery at Port Arthur;

Sun Company line which delivers oil to Sabine Pass, where it is loaded on vessels and delivered to the Sun Company Refinery at Marcus Hook, Penn.;

American Petroleum Company line connecting Humble with the tank farm of the American Petroleum Company at Houston.

Of the companies named, only the first three buy oil at Humble, and at the present time the oil must be marketed with one of them.

The American Petroleum Company (Cullinan interests) has thus far only utilized its line to take care of its own production. It has now in the course of construction at Houston a large refinery, where it expects to manufacture a full line of lubricating oils, and it has perfected arrangements it is said, with the Galena-Signal Oil Company of Pennsylvania to market its products.

DISCUSSION

Mr. Woodruff.—I have just one excuse for coming before you tonight, and that is I am more of a novice in the coastal plain country than the preceding speaker. Mr. Kennedy has been there for a long time and studied those salt domes carefully. In the coast country we look to him as the man who knows more about them than any one else. I am a novice and can therefore, I think, look on the salt domes as many of you will. More and more of you are coming down there all the time and I therefore presume to add some remarks to aid the elementary student to interpret the phenomena of the salt domes.

The first trip I made was to Humble where there is the dome Mr. Deussen has so carefully and minutely described. The Humble field is a pine woods country called Moonshine Hill but no hill is evident to the casual observer. The government has made a map of it on a one foot vertical scale and you must have the map laid down before you to really conceive that there is any relief. Can you imagine a man going down there looking for a salt dome in a country of that kind? The field men told me of the cap-rock and of course I listened to

them but could not at first comprehend what that was. I finally found that there was a salt core of sodium chloride sloping upward as an ordinary cone with the top cut off. Stringers or sills branch out from the main mass. The covering of this salt core composed largely of cavernous limestone more or less impure, is known as the cap-rock. Some of these cavities are small, but others, we have reason to believe, are several feet in diameter. Crystals of calcite line many of the cavities. Within the cap-rock these cavities probably unite in a network produced by the solution effects of ground water. The cap-rock oil is stored in these cavities.

To show you how the cap-rock is cut I may relate to you an experience we had down in Hoskins Mound. We leased the mound and the surrounding area for the purpose of drilling it. We decided to make a deep test just off the cap-rock. Hoskins Mound covers about a square mile in area and rises about 28 feet above the surrounding plain. We made our first location where the plain meets the rising land of the mound and missed the cap-rock entirely. Drilling difficulties caused us to abandon the well at something over 3000 feet depth. A second location was made 400 feet nearer the center of the mound and 600 feet from the first. In this well they struck the cap-rock at about 900 feet depth. The last I knew of the well they were still in cap-rock at over 1300 feet depth. In other words they had over 400 feet of cap-rock in the second well and missed it entirely in the first which was only 400 feet farther from the center of the mound. This will give you an idea of how distinctly the cap-rocks are limited. They cover only the top of the salt.

As soon as you pass the edge of the cap-rock the beds dip rapidly away from the dome, some places as much as 30 degrees. One thing I think Mr. Kennedy and Mr. Deussen have overlooked mentioning and that is the faulted condition of the beds around the sides. The beds are faulted and as near as I can tell are faulted radially to the domes.

If one is to study the salt domes I know of no better place to start than the salt domes on the west side of the Sabine uplift in Anderson County, Texas. If you want to get a good start go to the West Point dome near Palestine. I want to tell you the best place because we have most of it leased up. That

dome has been eroded to such an extent that the structure has been reflected in the topography very well. Sandstone caps the dome which rises 20 to 25 feet above the surrounding area. A shale is the next succeeding upward stratum. It has been greatly eroded and leaves a race track clear around the dome. The next stratum upward is a harder one which forms a little escarpment facing the dome and with a gentle dip slope receding from the dome. A view of this area gives one a definite idea of those domes. One should next examine the Salt Works dome at Palestine. Along one of the ravines on the south side you will see the succeeding strata one after the other gradually decreasing in pitch for a quarter of a mile. In one or two places you will find faults actually displacing the strata. These two domes give one a very good idea of dome topography.

To study the small mounds which are another phenomenon of coastal plains geology, go to the north side of the West Point dome where the sandstone comes down in contact with the shale, which forms the race track. Here you will find some soft muddy places slightly elevated. They are ten or twelve feet in diameter and are a foot or two in elevation. Some of them are in active formation and others, we might say, have stopped growing. It seems to me these mounds are formed by the water falling on and seeping down through the sandstone until it comes to the saturated zone below. The water comes up through the edge of the shale bringing a little of the clay with it, in sort of an artesian fashion, thus forming a little mound. In the coast country where you have a heavy massive sandstone dipping to the south under the Beaumont clays, the sandstone saturated with water under artesian head, and this water coming up through the very sandy clays bringing some of the clay to the surface with it, you have a possible origin of many of the mounds of the pimple plain.

In one of our wells we penetrated more than 3000 feet of solid salt, and in another we went into the salt nearly that much. Our driller made a record on that well. We put the well down 5410 feet in forty-five days. We were still in salt and could have gone deeper. One of the interesting things about that well was some salt crystals obtained near the bottom. I am going to ask Mr. Powers to describe them. You took them to Washington and studied them, did you not?

Mr. Powers.—I did but they have not been returned.

Mr. Woodruff.—I suppose I will have to describe them. They were little square rather flat crystals about one-eighth of an inch in diameter, with a small spot in the center. They were perhaps one-sixteenth of an inch thick. When viewed in section, the material was arranged in such a way as to give the impression of regular squares on each side. It seemed to me I could detect some oil in them, though I have never tested them for oil. These crystals were examined in the Geo-Physical laboratory in Washington to see if they showed evidence of stress, but they did not. They came from around 5000 feet depth and under normal conditions that would represent considerable pressure. I have some other cores I am planning to send to the laboratory to determine if they show crystal stresses, which they should show if the salt is intruded as some suppose.

We drilled a well at Hockley, about thirty-five miles northwest of Houston, which should be mentioned in connection with the salt in the coast country. It is here that the coastal plain gives place to the higher lands to the north and the southward dipping beds begin to form moderate escarpments. The well went through more than a thousand feet of salt. I cannot interpret it as a dome. We did not put down a second well in that vicinity. The question arises, are there other conditions in the coast country where salt beds are deposited besides the salt domes, and from which the ground water may have derived its salt and redeposited it in the domes.

Another one of our peculiar conditions is that there are different grades of oil in the same strata. We have wells not over two hundred feet apart and apparently in the same strata in which the oil is quite different. Especially the lubricating stock of those oils is quite different. The chemists have asked me what I can suggest and I cannot suggest anything only they are different.

If any of you come down to the coast country you will find we are not going to tell you very much but we will be glad to give you a start. There is an especially reticent feeling among the oil companies there. I don't see how our friend, Mr. Deussen got along at Humble as well as he did. Our company has some four hundred logs and we keep them pretty well locked up. We have come to about the same conclusion

as he did. In closing, I wish to apologise for these supplementary remarks and as I said before my only excuse is I am so much of a novice I feel I can represent the feelings of many here. Not that I know the conditions better than Mr. Kennedy or Mr. Deussen, but because I have sèen the domes so much more recently the impressions of the novice are firmly fixed in my mind.

Mr. Thomas.—I should like to ask Mr. Woodruff, if he is at liberty to state, why those gulf coast companies drill so many wells so deep into the salt. Is it purely missionary work?

Mr. Woodruff.—One of them, the first well we put down, was located by a gentleman down there with an instrument. He said you will not get any salt here but you will over there two hundred feet. So we said, we will just take the location where there is no salt. We struck the salt at 1340 feet depth and kept on going to over 4400 feet. On the second well the president of our company said "I want to know where the bottom of that stuff is." After we had gone a little over 5000 feet he changed his mind about it. To the best of my knowledge these are the only holes drilled to that depth.

Mr. Kennedy.—There are two 3000 foot holes, I think.

Mr. Woodruff.—In some of the cap-rock we are finding considerable breccia. I have one sample of an eight inch core with the rocks considerably brecciated. I have another at Hoskins Mound that I have not brought in yet. It is an eight-inch core four feet long. If I can I will have it split full length. It shows considerable breccia. I don't know what to make of that breccia, unless it is that in places the cavities became so large that the sides of them caved in. Those who are working in the coast country should watch to see if brecciation is due to movement of cap-rock material or simply the caving of the cavities of the cap-rock.

Mr. Hartley.—Do you find any faulting that lines up with the old Parsons alignment?

Mr. Woodruff.—No, there is nothing of that kind. I think, in fact, nothing that shows any faulting over a considerable distance. There is no evidence of any two miles in length. They are all shorter than that.

Mr. Hartley.—Do they show any persistence in depth?

Mr. Woodruff.—We don't know about that. The one I know on the Humble dome must be 3000 feet in depth. The throw is not over 300 feet. Those on the Salt Works dome at Palestine are displayed on the surface and have only a few feet throw.

Mr. Hartley.—Is that faulting subsequent to the formation of the dome, or has it ever affected the dome?

Mr. Woodruff.—I think it is concurrent with it. I think it is part of the dome where the stresses produced the fissures.

Mr. Hartley.—Have you ever known the salt being actually faulted.

Mr. Woodruff.—I have never seen anything to indicate that the salt core has undergone any movement. In the examination which is to be undertaken, some of our cores may show movement. I anticipate they will. Speaking of bridgings, I had the pleasure of looking over a number of cores of cap-rock in which there had been promiscuous faulting, on a very small scale. There were two or three systems of faults running at different angles through the core. There were films of sulphur along these fractures.

Mr. Deussen.—In connection with the faulting of the cap-rock, I might mention that the evidence is plain that the growth of the salt core is not one growth, but the result of several different movements at different times, as was shown in those Anderson County domes. We not only get a conformity of the upper portion but you get a tilting of the Wilcox beds at a high angle around those domes. The coastal domes also have two distinct movements. If the cap-rock is formed at the end of the first movement, there might be subsequent growth and faulting of the cap-rock.

Mr. Kennedy.—In our well at Vinton, after going through two hundred feet of sulphur and fifteen hundred feet of salt we got an oil sand and a well. This is an instance I know of that oil was found beneath the salt.

THE SALINE DOMES OF NORTHWESTERN EUROPE

By W. A. I. M. Von Waterschoot van der Gracht,

Tulsa, Oklahoma

(Norman Meeting, January, 1916.)

Saline domes occur all over the great Cretaceous and Tertiary plains of Northwestern Germany and Holland. They are a great help toward solving the mystery of these much discussed structures, which are of so great economic importance, be it as producers of oil or gas, or as salines or salt and sulphur mines in many parts of the world. The saline domes which occur elsewhere, notably along the Gulf Coast in this country, have been investigated only by ordinary wells drilled for the production of oil, brine or sulphur, consequently not very much is known about the details of their structures, much of which is yet a geological puzzle. The North European domes however, are of a very special value on account of the potassium salts occurring with the sodium chloride. They have been tested by thousands of holes drilled with the diamond drill under competent geological supervision, and minutely careful inspection of all the cores obtained. Moreover, they have largely been opened up by large mines, working the salts. As a consequence every minute detail of their structure is now very well known and fairly generally understood, and this knowledge is of special importance in the explanation of other similar saline domes in other parts of the world. It may, therefore, be of interest to discuss our present knowledge of these structures and their probable causes.

The deeper geology of the North Germain plain, the adjoining plains of Holland and Denmark and the North Sea was until recently but very incompletely understood. Only within the last ten or twelve years have hundreds of very deep diamond borings, exploring for salts or coals, disclosed the structure of the deeper regions. Such borings have been made to depths exceeding 6000 feet, and complete series of large size

cores (8"-4"), including the salt itself, procured. I was fortunate enough to take a rather prominent part in these explorations.

The great plains of Northwestern Europe extend to the north of an old continent, composed of the now deeply eroded old trunk blocks of the Permo-Carboniferous mountain ranges of central Europe, which gradually dip to the north under an ever thickening cover of Mesozoic and Tertiary deposits, which gradually attain a thickness of not less than 15,000 to 20,000 feet. Near the coasts of the North Sea and the Western Baltic this blanket consists of about 2,500 to 3,000 feet of Triassic, 1,500 to 3,000 feet of Jurassic, over 6,000 feet of Cretaceous and over 5,000 feet of Tertiary, not counting a glacial drift which might attain 750 feet The old Paleozoic floor consists of Carboniferous and Devonian, unconformably overlain by a great thickness of upper Permian red marls and dolomites, containing a nearly continuous deposit of rock salt, averaging about 1000 feet in thickness in the southern area of its deposition, but increasing to more than 2,000 feet further north, and possibly considerably more in the deeper basins, where the original mother bed has never been reached. This rock salt contains intercalations of the valuable potassium salts. There is an enormous break and unconformity between the pre-Permian and the saliferous beds.

The pre-Permian floor at the time of the deposition of the upper Permian was by no means an even surface, but consisted of a series of basins separated by higher ridges. Several cycles of earth movements have effected the region periodically during the upper Mesozoic and Tertiary and even in the Pleistocene, warping the beds into a series of folds but more often breaking them up through faulting into innumerable blocks which have moved vertically as well as horizontally against each other. Thus the beds have yielded to lateral pressure usually by breaking up into blocks rather than by bending into folds. Regular folded anticlines and synclines were formed less often than zones of upthrusted blocks near to regions of depression, caused by the same forces. Deep exploration has demonstrated that as a rule the structure is considerably more pronounced in the deeper beds than in the surface strata, because the deeper

beds have been affected by all the cycles of disturbance, while the often almost undisturbed surface strata have received only the latest after effects.

The lateral compression has been most intense toward the central parts of the deeper geosynclinal basins, wherever increased subsidence has accumulated the greatest thickness of sediments. This is a well known fact all over the world. The old Paleozoic blocks and ridges themselves have scarcely been refolded, but they have very often continued to rise spasmodically during the periods of disturbance, whilst the intervening basins have continued to subside and were crumbled into blocks or warped into folds. Thus we find even now, Carboniferous blocks at or quite near the surface in Northwestern Germany and Eastern Holland, in regions where the Mesozoic and Tertiary series sometimes attain a thickness of 15,000 feet normally. The best known of such uplifts is the small carboniferous coal field of Osnabruck in the Teutoburger Wald of Northwestern Germany.

The lines of weakness indicated by anticlinal folds, or rather more often by broken regions of upthrusted faulted blocks, strike along two main directions. The principal direction all through Northwestern Europe is WNW-ESE, a direction, which is traceable all through the plains from Southeastern Poland, through all Germany and Holland into Eastern England and is apparent even far into Asia. Across these lines of weakness strikes another in a generally SW-NE direction, although this latter one adapts itself more to the general outlines of the original basins of depression and therefrom varies considerably in strike. Wherever either borken or folded anticlinal zones intercross, it is natural that especially high uplifts occur, be it folded domes, or highly upthrusted blocks or "horsts", surrounded by faults.

The main periods of disturbance occurred in the later Jurassic, in the middle of the upper Cretaceous (at the beginning of the Senonian), and twice in the Tertiary—in the early Oligocene and in the Miocene. Several minor disturbances occurred between these main spasms and even continued into the Pleistocene. The general effect was a gradual continued subsidence of the whole region of the plains, all through the Meso-

zoic and the Tertiary, but spasmodic uplifts of certain areas took place along the lines of weakness, especially when such belts intercrossed, thus releasing the accumulating lateral compression.

It is on these lines of weakness that we find the saline domes: upthrusted plugs of Permian salt rock pressed upwards through maybe tens of thousands of feet of overlying beds. They naturally are most prominent where the compression was the most intense, to-wit, in the heart of the deepest basins.

In the Northern plains where the post-Permian sediments reach an enormous thickness, these domes consist of only a small round or elongated plug of salt, red Permian marls and rock salt, appearing amidst apparently undisturbed horizontal Tertiary strata, only slightly upturned at the edges around the saline core, making the whole a small "dome" with a central mass of salt. The salt itself has been partly dissolved out by surface waters usually to within some 500 or 600 feet of the surface, consequently it is now capped by a mass of gypsum and dolomite, residues of the eroded top of the plug now cemented into a hard cap-rock. A depression is sometimes traceable over the saline center, but mostly this is now filled with an increased thickness of glacial drift, older Pleistocene, or even late Tertiary. As a rule red Permian marls and often blocks of massive Triassic sandstones or limestones have been pushed upwards with the salt, and now appear near, or sometimes even at the surface, sometimes standing out in relief as curious red rocky hills amidst the Quaternary plain. The most striking of these is the red rocky island of Heligoland in the North Sea, off the mouth of the Elbe river. It is curious that where the original rock salt, from which the saline plug originates, lies very deeply buried, blocks of the overlying Mesozoic beds are much more rarely pushed up along with the saline core than the nearly regularly represented soft and plastic Permian red marls. In many instances however we find near the apex of these saline domes, comparatively small broken areas of Cretaceous, Jurassic and Trias intricately mixed and faulted, the blocks rarely measuring more than a few hundred feet across Only where the depth of the saline bed-rock is comparatively small, near the rim of the basins, do we find more regularly uplifted domes,

contoured by successive outcrops of more or less the entire series of the Mesozoic strata, although the saline plug has nearly always been pushed right through the succession.

It is very curious how little of the enormous disturbance appears at the surface. Most of the saline domes lie in an apparently unfolded, or unfaulted area, and over the entire district the surface strata appear almost undisturbed. The hidden top of a saline dome is discovered at comparatively shallow depth. The explanation is evident, and fully borne out by logs of borings on and around the structure. The saline core and the accompanying older formations have gradually been pushed up, but all dome-like uplift of the overlying beds was removed entirely before the latest strata were laid down, which now form the surface. Only if a renewed uplift has quite recently, slightly raised the hidden structure, is there a slight mound in the landscape. Much more often, however, solution of the top of the salt core has caused a depression over it.

Only rarely, as is the case of Heligoland, do the older formations pierce the recent surface beds and stand out as bold hills of red rock. The majority of the saline domes are entirely hidden, and indicated by nothing whatever at the surface.

Thus a great variety of saline domes could be described from the hundreds that have been located all over the enormous area from Southern Germany to Eastern Holland and the Danish border. It would take too much space to go into further detail here. The main point is, however, that invariably the rocks associated with the saline core prove that the plug has its roots in the Permian rock salt, however great the depth of this latter may be, even up to 20,000 feet. Very many of these saline cores contain rich streaks of potassium salts in the sodium chloride and are worked by extensive mines. Wells have been drilled in the central plug, which pierced 4,500 feet of solid rock salt, without reaching the lower limit, (Heids—NW of Hamburg).

In accordance with the tectonic lines of the region, mentioned before, the domes occur in marked belts, generally of NW-SE direction, the most marked of which is the Elbe-line.

from Wustrow (Salzwedel) over the domes of Luneburg, Patterson, Harburg, Stade, towards Heligoland in the North Sea. Even further out in the sea some areas of "red sand" at the sea bottom suggest the possibility of further upthrusts of Permian beds.

From the foregoing lines it will be clear that I consider these saline plugs as having been *pushed upwards* by orogenetic pressure, and not by recrystallization forces inherent in the mass of rock salt. It is my firm belief that the intense lateral pressure has caused the rock salt to behave as a plastic mass and has squeezed it upwards not unlike a volcanic neck, wherever the overlying strata afforded a weak spot inviting a passage. That chloride behaves like a plastic body in effect under intense pressure, has been proven experimentally by F. Rinne and A. von Koenen, although of course, it is understood that in reality the motion is of quite a different nature, in which probably recrystallization plays an important part.

Recrystallization takes place certainly under such circumstances, but as *an effect* and maybe as a help, but *not as a cause*, the same as limestones become recrystallized into crystalline limestones and marbles. Nobody has yet been able to explain physically this alleged mysterious recrystallization *force*, as a *cause* of the upward movement of a saline plug against the overwhelming load of tens of thousands of feet of strata. Increase in volume, such as takes place where anhydrite turns into gypsum, does not come into play here, for the sodium chloride does not change its chemical composition. Moreover, it is only in the cap-rock that we find gypsum, while in the deeper saline core only unchanged anhydrite is met with. Consequently, the embodiment of more water seems out of the question. We further find the intricately wound streaks of potassium salts in the saline plug are disturbed in such a way, as would naturally happen when part of the original salt bed, containing these streaks in parallel horizontal layers, were squeezed out through a comparatively narrow passage.

There exists in Europe another region of saline domes, which has been explored geologically to a considerable extent, and fully corroborates the theory that the saline plugs are

squeezed upwards through orogenetic pressure and not through inherent "recrystallization forces" of a mysterious nature. *I refer to the oil producing saline domes of Roumania.*

In the Roumania Tertiary plain, to the south of the Carpathian range, here called the Transylvanian Alps, occur various anticlinal folds, parallel to the strike of the mountains and decreasing in intensity as we proceed away from these to the south. On these anticlines the main oil fields of Roumania are located. Most of them are an intermediate structure between a pure saline dome and an ordinary anticlinal fold, having a saline mass in the apex, which like the plug in saline domes, pierces the overlying series of strata. This has been especially well investigated in the oil fields of Tzintea, Baicci, Moreni, Furu Ochnitza and Ochiuri. The stratigraphy of this region is as follows: The Miocene is developed in a saline facies, an enormous thickness of gray gypsiferous marls with great irregular lenticular bodies of rock salt. Overlying this formation are up to ten thousand feet of Pliocene clays, marls and sands and finally the Quaternary outwash gravels of the Carpathians. The saline cores of the anticlines mentioned here are real plugs, having been pushed right through the entire sequence of overlying beds and now reaching the surface. That orogenetic pressure was the cause of these upthrusts is evident from the whole structure of the region. We find, however, that fairly often the continuing lateral compression has squeezed out the stem of the salt core, perhaps even to the extent of entirely separating the saline mass at the surface from its roots in the Miocene. Many oil wells traverse the saline plug, with its accompanying Miocene marls and touch the Pliocene underneath where they got an enormous flow of oil from the fissures bordering the salt.

Finally, it might be of interest to add a few words on the relation between saline domes and oil. It is a well enough known fact that these structures are often heavy producers of oil and gas. It seems, however, that this is by no means caused only by their structural features such as domes, allowing oil to travel upwards in the sloping sands, towards the apex of the dome, but that there seems to be a decided action of the salt in them on the oil contained in the primary deposits where it was formed. It is nowadays fairly generally understood that

oil contained in sands is practically always secondary, but that the primary oil formations are bituminous marls and clays (or shales) from which the oil and gas have, through some cause, migrated, finally accumulating in porous beds: sands, sandstones, limestones or chalks. It seems as if salt water had a special faculty to liberate oil from the little pervious mother strata and that consequently the presence of a saline plug traversing such strata, and salting the ground water, was a special means to set oil and gas free, causing them to accumulate around the salt, especially in the fissures bordering the plug. This seems quite plausible as an explanation of the few small oil fields of NW Europe: Wietze and Oelheim. Here saline cores traverse the "Wealden" beds at the base of the Cretaceous, which contain highly bituminous estuarine shales. The cavities of fossil shells contained in them sometimes are even filled with a few drops of a heavy oil. Evidently this primary oil would not readily migrate, as sandstone layers in these shales are never oil bearing, even on well formed anticlines, which have often been tested for this purpose, as, for instance, near Bentheim on the Holland border, where the Wealdon beds are especially oily, having even caused small seepages and some deposits of asphalt. The only oil production ever obtained in the northern plain, has been on the edge of some saline plugs traversing these shales, where the oil collected in the fissures, and from their impregnated beds of sand a short distance from the core.

I hope that the above short notes may prove of interest in this country. I think it might be especially interesting from a scientific, as well as from a practical point of view, to try to get any evidence of the mother stratum that the saline plugs along the Gulf coast have originated from. I am not sure that any indications of the possible presence of saline formations have ever been found along the outcrops of the Cretaceous of the Gulf basin. Could it be possible that here also we have Permian salts? The great depth is no objection, since the Permian plugs pierce 18,000 feet of strata in Europe! If so, it would be likely that some traces of red Permian marls could be found in the wells in or around these domes. There might be even a possibility of finding deposits of the much longed for potassium salts as streaks in these saline plugs.

NOTES ON THE TEXAS PERMIAN

By W. E. WRATHER, *Wichita Falls, Texas.*

(Norman Meeting, January, 1916.)

The record of the Spur well, described by J. A. Udden, (Bul. No. 363, Univ. of Texas, Oct., 1914.) is of great interest to geologists in connection with the study of the Permian formation of Texas. This well was drilled to a depth of almost 4,500 feet and a systematic collection of drill cuttings was preserved from a depth of 2,300 feet to the bottom of the hole. In addition, a somewhat less complete collection of samples was secured from drill cores taken at shallower depths. The well location was in Dickens County, Texas, near the plane of unconformity between the Permian and the Triassic. It thus penetrated the greater part of the Permian, which is exposed in surface outcrops on the east side of the High Plains and the cuttings showed conclusively that the lowermost several hundred feet of the hole was in Pennsylvanian strata.

During recent months continuous surface sections have been made by the writer, westward along the line of dip from the top of the Cisco Beds in southeastern Shackelford County, to the top of the Double Mountains in Stonewall County, which serve as a standard of comparison for the record of the Spur well. From Abilene to Sweetwater a section of the Permian was made along the base of the Cretaceous hills on the south side of the Texas & Pacific Ry. Further progress in a westerly direction beyond Sweetwater proving difficult on account of slight relief, the section was resumed along the Double Mountain fork of the Brazos River about thirty miles north of the above railroad. The Merkle dolomite was traced across country and was used as a basis to correlate the two sections.

Acknowledgments

Dr. J. A. Udden prepared the section including that portion of the Wichita Beds lying above the Lueders Limestone and below the base of the Clear Fork Beds. Mr. W. A. Riney, of Abilene, Texas, computed the thickness of the Clear Fork

Beds from numerous observations of the dip in Taylor and Jones counties. Especial thanks are due Mr. Riney for assistance in the preparation of the two sections both in the field and in the office.

Definition of Terms Used

Wichita Beds: A definite horizon has never been agreed upon by geologists as the boundary between the Wichita Beds and the underlying Cisco. For several reasons the boundary has here been placed at the base of a series of yellow-weathering limestones found in the hills about two miles west of Moran in Shackleford County. At this horizon the near-shore, shallow water deposits of the Cisco terminate, and a marine type of sedimentation begins, which is continuous upward through the Wichita formation. Sandstone and sandy blue clay are plentiful below while above they are scarce or entirely absent. At about this horizon also, a change in the character of the fauna takes place, new forms appearing which persist upward through the beds of the Albany Mountains.

For purely lithologic reasons, the Wichita Beds are made to include all the limestone beds up to the transition to the red clays of the Clear Fork Division. Throughout North Central Texas, it has been found convenient to place the Lueders Limestone (named for a small town on the Clear Fork of Brazos River, in eastern Jones County), at the top of the Wichita Division. This horizon has been identified by the writer from a point south of Harrold on the Fort Worth & Denver City Railroad in Wilbarger County, past Seymour across northwestern Throckmorton and southeastern Haskell counties, near the east boundary of Jones and Taylor counties, to Ballinger in Runnels County. It is approximately accurately mapped by Gordon (U. S. G. S. Water Supply Paper No. 317) and is believed to be about the horizon followed by Cummins which led him to adopt the correct view that his Albany and Wichita beds were one and the same (Tex. Acad. Sci. June 15, 1897, pp. 93-98). Around Abilene and perhaps southward beneath the Callahan Divide, 170 feet or more of thin limestones and light colored clays occur above the Lueders Limestone, which properly belong to the Wichita Formation. Going northward, these thin limestones thin out and disappear, though the Lueders limestone persists to within a few miles of Red River.

Clear Fork Beds: The Clear Fork Beds are here considered as including the red clays, two thin dolomites, and thin sandstones to the base of the Blowout Mountain Sandstone. The strata are generally soft and unindurated and weather down into a relatively level plain,—a topographic unit, extending from Abilene westward to beyond Merkle which is readily noted from the car window along the Texas and Pacific Railway.

Double Mountain Beds: The Double Mountain Beds are taken to include all the strata from the base of Blowout Mountain sandstone upwards to the base of the Triassic. For present purposes this single designation will be retained although it is realized that the name as used by Cummins was too general and that sooner or later, when the strata have been more carefully studied, the name will have to give way to a new, more precise grouping.*

Comparison of Sections with Record of Spur Boring.

The fossils identified in the cuttings from the Spur well seem to indicate quite clearly and definitely that the top of the Cisco Beds was penetrated at about 4,100 feet. The total thickness of the strata according to the sections from the top of the Cisco Beds to the top of the Permian in the Double Mountains is 3,230 feet; hence the Spur well penetrated some 870 feet of strata, which are stratigraphically higher than anything shown in the surface sections.**

The strata shown in the columnar sections are the probable equivalent of those penetrated in the Spur boring between the depths of 870 and 4,100 feet, leaving out of account any possible thickening or thinning of the beds in the 50 miles between Spur and the Double Mountains. In that distance it would hardly be expected that there would be such a marked lateral change as to render the same beds unrecognizable. Yet a remarkable dissimilarity is disclosed on comparing the log with the section. The Spur record shows that massive dolomite

---

*The local names attached to formations are for purposes of local identification only, as no effort has been made to learn whether they have been preempted in geological literature.

**It should be borne in mind that all the exposed Permian in Texas is not included in the sections; probably near 1,000 feet of stratigraphically higher beds might be added by continuing the section up the Double Mountain Fork of Brazos River to the foot of the High Plains.

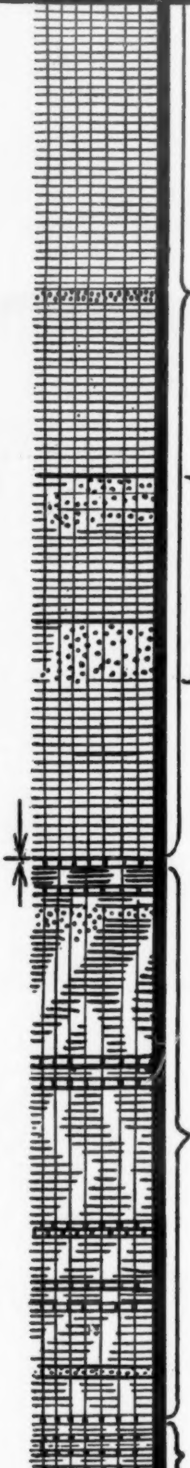
beds were found at about 1,250 feet below the surface and continued with few breaks to the top of the Pennsylvanian Limestone at 4,100 feet. The top of the dolomite in the well, assuming a constant thickness of the strata, is 380 feet below the top of the Permian of the section. The soft red sandstones, red clays, massive gypsum and insignificant dolomites of the lower portion of the Double Mountain Beds, all of the Clear Fork Beds and the limestones and blue clays of the Wichita, have within the 50 miles evidently undergone a transition to the section described by Udden as the "Dolomite Beds."

Wichita Beds: A more careful scrutiny shows that evidence is not wanting as to the equivalency of the beds in question. The one thousand feet of dolomite overlying the supposed Cisco Beds in the Spur boring is predominately massive, with minor thicknesses of inter-bedded shales and little or no sand. Anhydrite was noted to be in smaller quantities than in the upper 1,750 feet and decreased downward from 15 to 4 per cent of the volume of the rock. Udden states that it was all quite clearly of secondary nature indicating that it had been introduced subsequently to the deposition of the beds. Minor amounts of chert are reported from a depth of about 4,000 feet, that is, near the point where the base of the Wichita Beds would be expected.

This evidence is in keeping with the observations made along the outcrop of the strata. The Wichita Beds along the Colorado River are about 1,200 feet thick as determined by Drake. Fully five-sixths of the total thickness is limestone, with scarcely any sandstone. As determined by the writer, about 85 miles north of Drake's section, in Shackelford County, the thickness of the same beds is 1,350 feet, or 1,180 feet below the Lueders limestone. Of this section about five-sixths of the total thickness on the outcrop is marly clays, and blue to dark-colored clay shales. It should be noted here, however, that throughout this area the limestones are generally soft and friable, weathering readily, and it can confidently be expected that within a short distance back from the outcrop a much greater percentage of limestone would be found.

Another very careful section was made across the Wichita Beds in northern Throckmorton County fifty miles north of the Shackelford County section, and the thickness was found to be about 1,025 feet. It will be seen that the thickness of Udden's

WICHITA BEDS



340′ Tye Formation. Soft red clays with thin unimportant sandstones in upper portion, weathering down to a featureless plain.

Buffalo Hill standstones, which cause an irregular range of hills west of Abilene.

170′ Abilene Formation. Thin limestones separated by red and blue clays. Limestones generally fossiliferous.

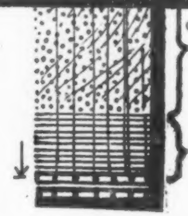
20′ Lueders Limestone.

GEOLOGIC SECTION

ALONG TEXAS & PACIFIC RAILROAD

FROM ABILENE, TEXAS, TO SWEETWATER, TEXAS.

Vertical Scale 50′=1 inch.



40′ Blowout Mountain sandstone.

20′ Red clay.

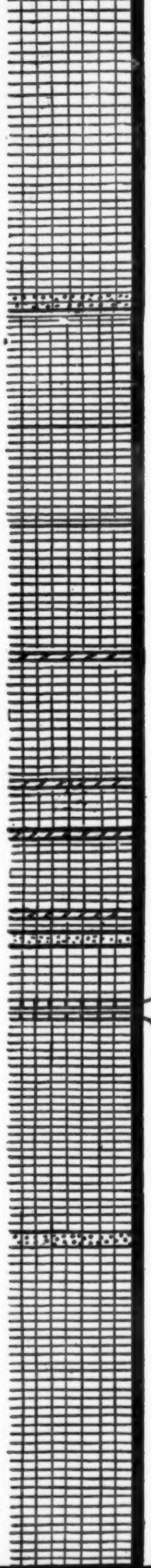
8′ Merkel Dolomite with 4′ clay parting.

GEOLOGIC SECTION

ALONG DOUBLE MOUNTAIN FORK OF BRAZOS RIVER FROM FLAT TOP MOUNTAIN, HASKELL COUNTY, TO TOP OF DOUBLE MOUNTAINS, STONEWALL COUNTY, TEXAS.

Vertical Scale 50′=1 inch.

CLEAR FORK (ENID) BEDS

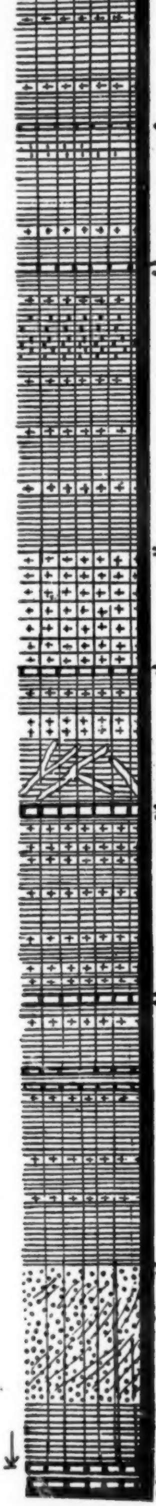


370′ Red clays with several local, lenticular grayish or red sandstones of minor importance. This section weathers down to a relatively level, mesquite-covered plain.

Through the 100′ of strata overlying the Bullwagon Dolomite are a number of strata of indurated beds of white argillaceous very fissile shale ranging in thickness from a few inches up to 2′ each.

5′ Bullwagon Dolomite with 3′ clay parting.

GREER FORMATION



1′ Aspermont Dolomite.
8′ Red clay.
1′ White gypsum.
15′ Red clay.
5′ Massive white gypsum.
10′ Red clay.
1′ Dolomite.

39′ Red clay with two thin strata of gypsum.

2′ Dolomite — sparingly fossiliferous.

83′ Vari-colored clays, with several thin strata of white gypsum.

34′ Massive, white, crystalline gypsum.

1′ Dolomite, locally very fossiliferous.

39′ Vari-colored clay, with abundance of satin spar, and several strata of white gypsum.

3′ Dolomite.

57′ Light colored clays, containing highly colored concretions of gypsum.

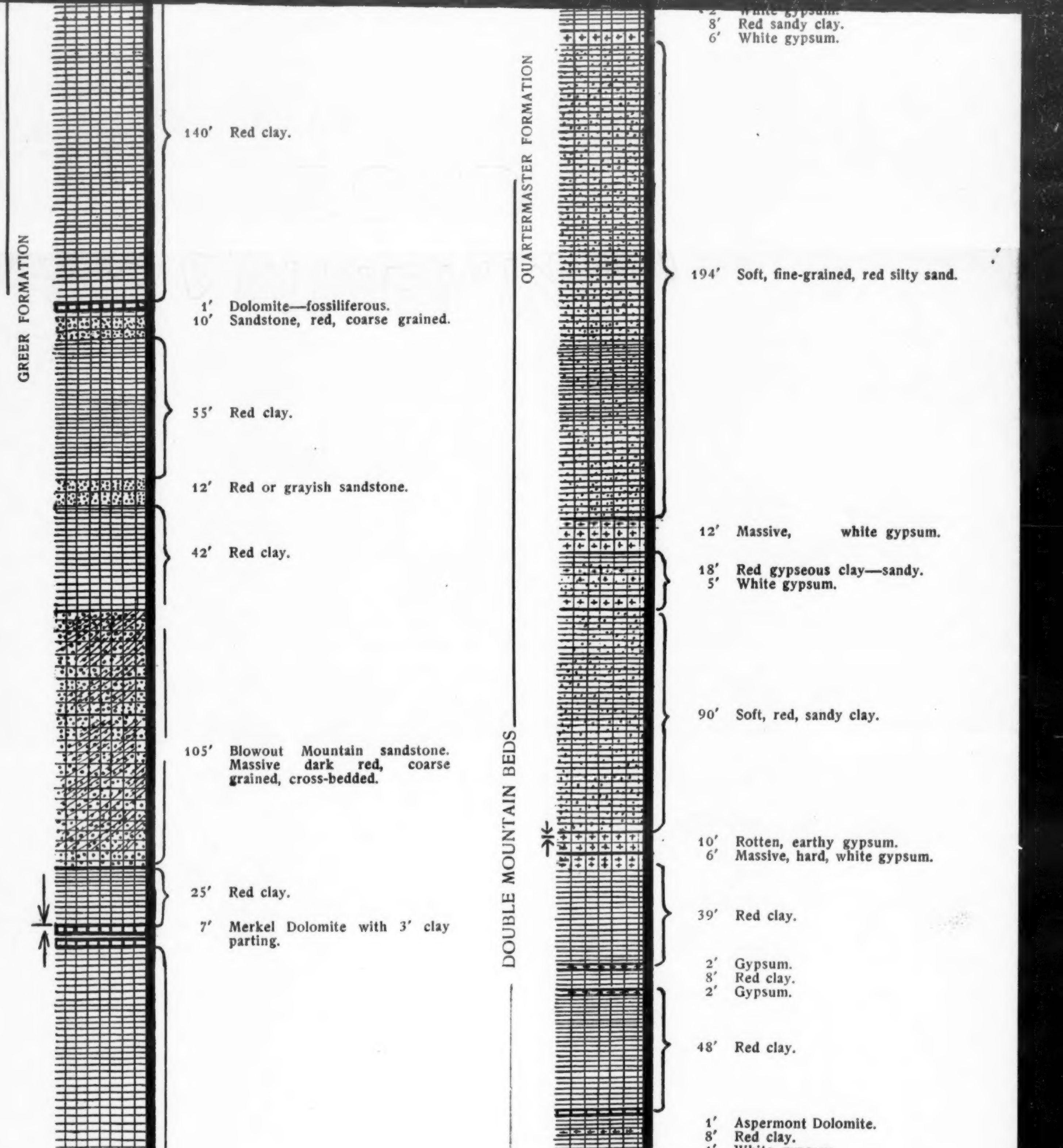
1′ Dolomite.

79′ Light colored clay, with concretionary gypsum and several thin dolomites.

40′ Blowout Mountain sandstone.

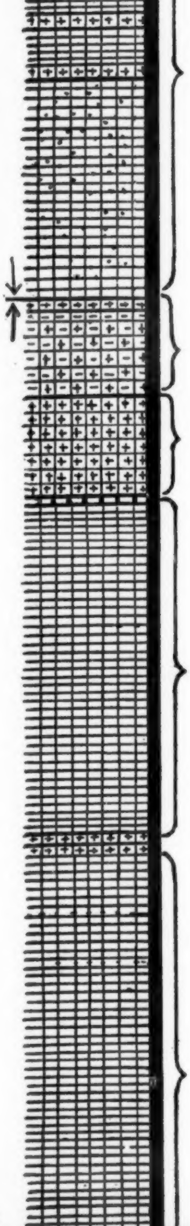
20′ Red clay.

8′ Merkel Dolomite with 4′ clay parting.


GREER FORMATION
140' Red clay.
1' Dolomite—fossiliferous.
10' Sandstone, red, coarse grained.
55' Red clay.
12' Red or grayish sandstone.
42' Red clay.
105' Blowout Mountain sandstone. Massive dark red, coarse grained, cross-bedded.
25' Red clay.
7' Merkel Dolomite with 3' clay parting.
DOUBLE MOUNTAIN BEDS
QUARTERMASTER FORMATION
White gypsum.
8' Red sandy clay.
6' White gypsum.
194' Soft, fine-grained, red silty sand.
12' Massive, white gypsum.
18' Red gypseous clay—sandy.
5' White gypsum.
90' Soft, red, sandy clay.
10' Rotten, earthy gypsum.
6' Massive, hard, white gypsum.
39' Red clay.
2' Gypsum.
8' Red clay.
2' Gypsum.
48' Red clay.
1' Aspermont Dolomite.
8' Red clay.

DOUBLE MOUNTAIN BEDS

ON



130' Red sandy clays with four or five strata of white gypsum, ranging in thickness up to 3' each.

30' Gray to white earthy gypsum.

30' Massive white gypsum.

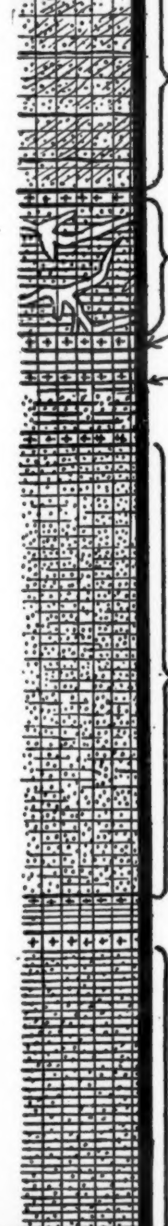
1' Dolomite.

100' Red clays.

6' Gypsum.

140' Red clay.

RTERMASTER FORMATION



70' Massive red, coarse-grained sandstone, cross-bedded.

3' White Gypsum.

42' Sandy red clay with fibrous gypsum.

3' White Gypsum.

5' Red clay.

2'

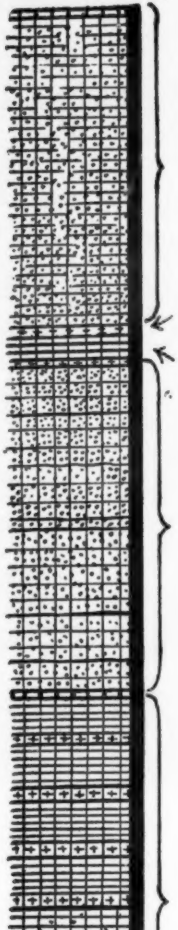
15' Sandy red clay.

4' Gypsum.

135' Soft red silty sand and red clay.

2' White gypsum.
8' Red sandy clay.
6' White gypsum.

QUARTERMASTER FORMATION



1′ Gypseous Sandstone.

93′ Red sandy gypseous clays.

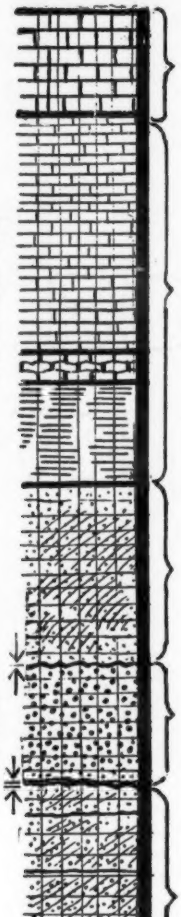
4′ Crystalline white gypsum.
7′ Sandy red clay.
2′ Crystalline white gypsum.

100′ Lake Trammel sandstone. Massive red soft sandstone. Disintegrates readily on weathered surface.

130′ Red sandy clays with four or five strata of white gypsum,

CRETACEOUS

Triassic



30′ Edwards Limestone.

115′ Comanche Peak series.

55′ Trinity sand.

35′ Quartz Pebble Conglomerate.

70′ Massive red, coarse-grained sandstone, cross-bedded.

"shaley dolomite beds" in the Spur well, corresponds quite closely with the observed thickness of strata along the outcrop of the Wichita Beds. The freedom from sand and the presence of interbedded-shale are in conformity with the character of the beds at the surface. Chert in the base of the beds is evidence of similarity also. The only chert noticed by the writer along the Shackelford County section was in the yellow-weathering limestones at the base of the Wichita formation west of Moran. The Wichita Beds are not noticeably dolomitic along the outcrop nor has anhydrite ever been noted. Udden states that the anhydrite in the "shaley dolomite beds" below 3,100 feet is clearly secondary and assumes that it originated in the dolomitization of the limestones "as the result of a reaction between magnesium sulphate in circulating solutions and the calcium carbonate of the original sediment." This explanation seems plausable and satisfactorily accounts for the presence of this unexpected mineral. The minute fossils such as would escape destruction in the cuttings recovered from a roller rock bit would scarcely be noticeable at the outcrop without more careful observation than was found practical in the course of field work, and for this reason it is not possible here to use fossils as a basis for correlation.

Clear Fork and Double Mountains Divisions: The change in the character of the Cleark Fork and Double Mountain Beds between the outcrop and Spur is much pronounced. A brief description of the section follows: (1) The 700 feet of the Cleark Fork Beds lying between the top of the Wichita Beds and the Merkle Dolomite is almost entirely without any indurated strata aside from the Bullwagon dolomite and several thin sandstones. The beds are almost entirely red clays, relatively free from sand as compared with the higher beds. The Bullwagon dolomite, composed of two distinct strata separated by a shale parting, (taking its name from Bullwagon Creek in Taylor County), is from two to four feet thick west of Abilene, and thins northward until it cannot be identified with certainty 35 miles north of the Texas & Pacific Railway. It occurs about 340 feet above the base of the Clear Fork Division. The Merkle Dolomite (named for a station on the Texas & Pacific Railway, just west of which it is exposed) occurs at the top of the Clear Fork Beds. The two dolomites

aggregate not more than ten feet in thickness. Both contain disseminated silica and no traces of organic structure were anywhere noted. They might well be chemical precipitates as near as could be determined in the field. Shallow water phenomena are beautifully preserved throughout these beds,—fossil rain drops; sun cracks; and within the area bordered by the sun cracks, are sometimes found ripple marks of diminutive size in impalpably fine sand. The Merkle Dolomite is characteristically ripple marked and weathers into thin plates, much after

Surface Markings of Merkle Dolomite.

the fashion of cross bedded sandstones. (2) Above the Merkle Dolomite, is the Blowout Mountain Sandstone (named from a typical exposure in Blowout Mountain southwest of Merkle) ranging in thickness from 40 to 100 feet; a coarse-grained, cross bedded, massive, red sandstone, which is a prominent factor in fashioning topography. (3) For 600 feet above the sandstone, strata of white massive gypsum, ranging from 1 or 2 feet to 35 feet in thickness, are numerous, the gypsum being most abundant at the base and decreasing in amount upward. In the lower 400 feet of the gypsum beds, where gypsum is particularly abundant, the clays are generally light colored, greenish, blue

or cinnamon, and contain smaller proportions of sand than is common in this division. In the upper 200 feet, very fine silty red sand is an increasingly important ingredient upward. (4) The top 600 feet is more pronouncedly sandy and when freshly exposed, it shows massive bedding, having at a distance the appearance of heavy bedded red sandstones. These sands are very friable and disintegrate readily giving rise to the loose red sandy soils found between Aspermont and the Double Mountains. Around the base of the Double Mountains they show characteristic erosion features, being deeply trenched with steep walled gullies, not more than 5 to 15 feet in width and two or three times as deep; pot-holed, grooved and trenched by abrasion, making progress on foot along the bottom of the gulches very difficult. Numerous small greenish spherical spots from one-sixteenth to one-fourth inch in diameter, were noted throughout much of the upper sandy clays, evidently due to leaching out of the red coloring matter. Six thin strata of white gypsum were noted, interspersed through the sandy clays, aggregating probably 20 feet in all. The topmost stratum of gypsum stands out as a prominent white band, visible for a number of miles on approaching the Double Mountains from the east. Underlying the Triassic conglomerate is 70 feet of hard, coarse-grained, red sandstone, massive and cross bedded.

Udden remarks (pp. 61-62) that "it is significant of the relationship of these sediments to the Red Beds above, that the sandy clay beds are both ferruginous and of nearly the same mechanical composition as in the Red Beds. Below 2,800 feet, these red clayey sands do not occur. In the Red Beds the sands and clays, and even some gypsum and anhydrite, are mostly of a deep red color." He refers here to the "sandy Dolomite Beds" which seem to represent both the Clear Fork and a portion of the Double Mountain Division. The sandy texture of these beds, both in the well and in the outcrop clearly indicates a relationship. The sections show that the basal gypsum beds of the Double Mountain Division include a number of thin dolomites. One of these was followed down the dip along the Double Mountain Fork for four or five miles. Along the surface outcrop back from the river, it consisted of several thin plates, each from 2 to 4 inches thick, but when it disappeared under the river up stream, it was fully six feet thick, a massive

solid ledge, in the top of which crystals of selenite several inches in length, had grown. This stratum is fossiliferous and is the ledge making the Falls of Salt Croton Creek, from which Cummins made a fossil collection (Second Annual Report Geological Surv. Texas, pp. 408). There it is 8 feet thick.

It seems probable that this thickening of the beds down the dip continues. If the indicated rate of thickening is persistent in all the dolomitic strata, it is apparent that within a relatively short distance, the strata would merge until they would be classed by a driller, when penetrated in a well, as solid dolomite, even though including thin shale partings.

It may be more than a co-incidence that the only two flows of water reported in the "sandy dolomite beds" at 2,050 feet and 2,980 feet, correspond quite closely in stratigraphic position with the Buffalo Hills Sandstone near the base of the Clear Fork Division, and the Blowout Mountain Sandstone. It is by no means to be assumed that these sandstone strata are continuous beds, but rather that they represent sandy horizons in which individual sands may be of more or less local extent. It would not be surprising, considering the persistence of the Blowout Mountain Sandstone along the outcrop, to find that it was a continuous sandstone horizon of varying thickness, though the cuttings indicate that its supposed correlate in the Spur well is of finer texture and more silty than on the surface. This is the horizon from which Udden reports potash in brine.

Udden notes particularly the oolitic structure of the dolomite cuttings. A number of observations have been made of the dolomite beds interstratified with the gypsum at various points from Red River southward, and oolitic structure was found to be common. The Strata capping the bluffs along Tonkaway Creek southeast of Aspermont were noticeably oolitic. The oolites seem to have weathered out on the surface, giving a very finely pitted or porous character to the rock. The ledge capping the Medicine Buttes in Southeastern Hardeman County shows the same characteristic. These ledges are locally quite fossiliferous.

A dissimilarity is to be noticed in that Udden's table of percentages of anhydrite in the cuttings shows that the highest percentages, ranging from 28 to 60 per cent, were found in the interval representing the Clear Fork Beds. This would hardly

be expected since the greater percentage of gypsum on the surface is found above the Blowout Mountain sandstone, (that is, in the basal Double Mountain Beds), which should place its correlate above a depth of 2,000 feet in the well. The clays of the Clear Fork west of Abilene nowhere show any gypsum of consequence. It is assumed here that the white surface gypsum should probably be the correlate of the anhydrite beds in the well. This may possibly be accounted for by the fact that the record of the interval probably representing the basal gypsum beds of the Double Mountain Division was very imperfectly sampled, only ten samples having been examined. A greater percentage of anhydrite in these beds might easily have escaped detection in this manner.

Summarizing, it will be seen that enough evidence is at hand to account for what at first sight would seem to be an unexplainable lateral transition. Near-shore, shallow water deposition seems to have given way to deeper sea sedimentation westward from the outcrop. Any differences in the character of the Wichita Beds are slight and may be disregarded. The distribution of the sandy and shaly strata through the "Dolomite Beds" are in agreement with observations on the surface; and the presence of oolitic dolomites, which seem to thicken westward, helps to strengthen the above conclusion. The main discordance is the unusually high percentage of primary anhydrite in the cuttings from the interval correlated with the Clear Fork Division, and the change from red clays to dolomites.

Notes on the Stratigraphy of the Permian of the Pecos Valley in Southeastern New Mexico.

The presence of the massive dolomite in the Spur Boring leads to further speculation as to the character of the Permian Beds underlying the High Plains, and brings up the problem of correlation of the Permian strata of the Pecos Valley with those of the east side of the Plains. A satisfactory solution of this problem from the study of surface outcrops is not possible, since erosion has not yet cut through the Tertiary capping of the Plains sufficiently deep to expose the stratigraphy of the underlying Permian. A meager knowledge can be had by studying the outcrop along the margin of the "Cap-Rock" but the closest points of comparison east and west across the supposed geosyncline of the Plains are from 100 to 200 miles apart with

the one exception of the valley of the Canadian River. Gould's papers (U. S. G. S. Water Supply Papers No. 154 and 191) point out the presence of two gentle folds in the Permian with an apparent north-south axis, one north of Amarillo, the other in Oldham County. Udden has recently studied the Marathon anticline of supposed late Pennsylvanian or early Permian age, south of the Plains, in Trans-Pecos Texas, and traced it in a northeast-southwest course until it disappeared northward under overlying sediments about 40 miles northeast of Marathon. At the point of disappearance he states that the Pennsylvanian strata were standing almost vertical, which suggest stress of mountain-making magnitude. These suggestions point to a deformation of the Permian underlying the Plains of which little is known. The knowledge that such folding exists makes the problem of the stratigraphy of the Plains Permian very uncertain, and it will never be worked out without the aid of carefully preserved deep well records, of which there are at present all too few. Udden made a careful study of such well records as were available adjacent to and on the Plains, publishing the results of his investigation in his paper on Potash in the Texas Permian (Bul. Univ. Tex. 1915). One of the most interesting disclosures of this paper is the fact that "Dolomite Beds" probably replace the Clear Fork clays, and possibly also a portion of the basal Double Mountain Division, down the dip as far north as Red River.

Along the Pecos River in southeastern New Mexico, the gypsum beds forming the east bluff, contain a much greater percentage of limestone and dolomite than on the Texas side. The logs of artesian wells in the Pecos Valley show that relatively thin limestones, red shales and clays, red sands and gypsum make up the series to a depth ranging from 400 feet at Roswell to 800 feet or more at Artesia. Below the porous water-bearing limestone which lies at the base of the above described beds are massive limestones, clays and possibly gypsum in a series of undetermined thickness but probably of Permian age. Fossils are scarce, but the writer made a small collection of casts of bivalves from the limestones around the Hondo Reservoir southwest of Roswell. The fossiliferous horizon near Roswell is believed to be near the outcrop of the water bearing limestone.

Fisher (U. S. G. S. Water Supply Paper 158 p. 8) and Richardson (Am. Jour. Sci. 4th Ser. Vol. 29, 1910, pp 330-332) both made meager collections presumably from about this same horizon. Their collections were found by Dr. Girty to include forms of Schizodus and Pleurophorus neither of which are possibly very determinative, though it has been the writer's observation that these forms are confined to a relatively definite zone on the Texas side from Quanah south to Roby in the dolomites which are interbedded with gypsum in the base of the Double Mountain Beds.

Dr. J. W. Beede found fossils in a limestone south of Lakewood, New Mexico, (cited by Richardson—am. Jour. Sci. 4th Ser. Vol. 29, 1910, pp 330-332) which he correlated with the Whitehouse-Quartermaster Fauna. This horizon is perhaps slightly higher stratigraphically than the fossil bearing horizon near Roswell. The Whitehorse Springs locality occurs in the Woodward formation as mapped by Gould (U. S. G. S. Water Supply Paper 148). Stratigraphically it underlies the Greer formation, the upper gypsum bearing beds in Oklahoma, the basal portion of which Gould maps along Red River opposite the lowest important gypsum horizon in Texas. Based upon observations of the writer in Texas, and of Dr. Gould in Oklahoma, it would seem that the Blaine Formation with its massive gypsum members does not occur south of the Wichita Mountains. If represented in Texas at all, it is local, and cannot be traced along the strike continuously. The upper gypsum bearing horizon in Oklahoma (Greer formation) seems to be continued southward in Texas by the basal gypsum beds of the Double Mountain division. It might possibly be that the Whitehorse Sandstone could be correlated with the Blowout Mountain Sandstone, though this is by no means certain. At any rate, this fossil horizon, compared with the Texas section, is perhaps somewhere near the base of the Double Mountain Beds.

The Dozier Mound fossil horizon (Gould U. S. G. S. Water Supply Paper 154 pp 22-23) occurs in the Quartermaster formation and is possibly 500 feet higher, according to Gould's figures, than the Whitehorse horizon which would probably place it in the Texas section near the top of the basal gypsum member of the Double Mountain formation, as shown in the accompanying section. If so there should be an agreement be-

tween the fauna found at Dozier, and that in the dolomites in the Double Mountain section, when collections from the latter horizon shall have been studied.

It is the writer's belief on account of the lithologic similarity, borne out by the meager paleontologic evidence, and the disclosure of the radical change in character of the beds westward as shown in the record of the Spur well, that the beds outcropping around Roswell are, generally speaking, the correlate of the basal Double Mountain Beds. If this is true, it would indicate that the underlying massive Permian limestones outcropping west of the Pecos Valley artesian belt are the probable correlate of the lower portion of the Double Mountain, the Clear Fork and perhaps the upper part of the Wichita Beds, which beneath the Plains have undergone a transition to beds of a decidedly different character.

It seems possible in view of the foregoing evidence, that the Captain limestone with its peculiar Guadalupian fauna, is the deep sea facies of the beds which on the east side of the Plains are represented by the shallow water deposits of the Clear Fork and Enid formations. The migration of the Guadalupian fauna in this instance would necessarily have been from some other quarter than from the east, and since the beds are cut off and concealed west of the Sacramento Mountains, its local and isolated characteristics may be accounted for.

The artesian water horizon indicates a dip eastward of 40 or 50 feet per mile. The base of typically red sediments in a well six miles northeast of Roswell was found at approximately 400 feet and below to 2,080 feet the formation was predominantly light and dark colored limestone with minor breaks of sand and blue shale. A well 20 miles south of east of Roswell reports typical red bed formation to 1,625 feet, below which massive dark and light colored limestone was penetrated, which continued almost unbroken to a depth of 2,900 feet. The bottom to 2,943 feet was clay grading downward into blue shale. The surface elevations of these wells are not accurately known but allowing a difference of 300 feet, which based on the topographic maps cannot be far wrong, a dip in the surface of the massive lime of between 55 and 60 feet to the east under the Plains is indicated. The westward dip on the Texas side will perhaps average around 35 feet per mile which unless interfered

with by folding, would place the axis of the Plains syncline nearer the west margin than the east, or a short distance east of the Texas-New Mexico line.

Evidence of the Existence of an Ancient Inland Sea.

Any evidence, however meager it may be, which tends to throw light on the axis of the Plains Syncline, is worthy of recording. Besides being of great scientific interest, the accurate definition of this structural basin may be of economic importance also in the search for potash salts. It is evident that within the area of ultimate dessication of a mediterranean sea the precipitation of sodium and potassium salts would attain its greatest thickness.

That such an inland sea existed cannot be doubted. From the known Pennsylvanian, upward the lithologic changes are without any pronounced unconformity, from limestones to dolomites with abundant anhydrite. Higher yet, gypsum makes its appearance and in the youngest Permian strata, rock salt is an important member. At several places, located near the supposed axis of the syncline very small amounts of potash salts were identified by Udden in the rock salt. The association of the potassium and sodium salts seems to be identically the same geologically and mineralogically as in Germany.

Considered from a Paleontologic standpoint, we begin at the base with an unquestioned Pennsylvanian fauna, which gradually undergoes a change during the period represented by the deposition of the Wichita Beds, until at the top of this division, enough Pennsylvanian forms have dropped out or have become modified, for the fauna to be classed more as Permian than Pennsylvanian. When the sea had become so highly mineralized as to permit of the natural precipitation of gypsum, it is presumed that only the more hardy forms of life or those so specialized as to withstand the acrid water, survived, and a characteristic fauna is found within the gypsum beds. At one place on Shores Creek, near Childress, a band one or two feet thick was found within a massive bed of gypsum much of which seemed to be primary, which was literally a mass of small bivalve casts. This band had evidently been a dolomitic stratum which had been largely replaced with gypsum and in an unweathered state, the fossil casts were filled with clear selenite.

Finally when the point of saturation for sodium and potassium salts had been reached the existence of more than a very meager, highly specialized fauna was probably precluded. At any rate invertebrate fossils have not been reported from the beds known to carry salt.

Possibilities for Potash.

To date scarcely more than enough mineral potash has been found to enable one to state with certainty that it was present in the strata of rock salt penetrated in wells. However the discovery was largely accidental and it remains to be seen whether commercial amounts are present after the strata has been tested by borings made exclusively for this purpose. The basin occupied by the Plains would appear to be relatively shallow, judging from present information, though we have no idea of the thickness of the salt bearing horizon lying below the Tertiary and above the Dolomite Beds in the structural trough. It is doubtful whether individual salt strata more than several hundred feet in thickness will ever be found if the basin proves as shallow as is now thought, and according to our knowledge of the occurrence of potash in association with rock salt, it is probable that potash would constitute only a minor percent of the total thickness of any one bed. Large amounts of potash might be present in thin strata of wide horizontal extent and yet it would not be possible to produce it economically enough to make commercial exploitation profitable. One can only say with certainty that the Plains country along the trough of the syncline will remain a fairly favorable prospect for potash until it has been drilled and condemned.

THE VERTICAL COMPONENT IN LOCAL FOLDING

By James H. Gardner, *Tulsa, Oklahoma*

(Tulsa Meeting, February, 1917.)

The fundamental principles of isostacy are well established. The origin of regional elevations and depressions of the earth's strata has been definitely associated with tangential pressures set up by planetary shrinkage and the transfer of loads from land to sea. Long ranges of mountains paralleling the shore lines of our great oceanic areas and showing the effects of thrusts set up in a landward direction, bear testimony to the fact that the rocks of the earth are pliable and periodically adjust themselves. Every land stream of the globe from the smallest to the largest is constantly engaged in the work of erosion, transportation and deposition. Year after year, century after century, cycle after cycle the beds of the seas are burdened with added sediment at the expense of the land. Ultimately the limit is reached; the accumulated weight on the ocean floor depresses the shell of supporting rocks, and then an elevation on the land compensates for a depression in the sea. The surface of one continent rises, while the surface of another continent sinks, and all the while the total circumference of the planet is being shortened by shrinkage. The sedimentary strata are of minor importance in many of the great orogenic movements. The whole lithosphere is involved when a mass of abysmal rocks rise in the form of a mountain range. However, the laws of geophysics are applicable on a small scale equally consistently as on a large scale, and within this background in mind, let us view the local folding of the stratified rocks in their relation to mountain uplifts.

It has been the custom to attribute the origin of anticlinal and synclinal folding to lateral pressures set up on the strata by the emergence of plutonic rocks in the mountains that lie near at hand. To a certain extent this view cannot be altered. As a principle it must be true, but as a complete explanation of local folding in some regions, it must be materially altered.

For instance, a zone of long parallel axes of anticlines and synclines such as run throughout the Appalachian Valley was unquestionably produced by pressures acting largely along the tangent. However, it is probably true that in most cases the first break of resistance was in the profound depths far below the sedimentary strata, and that the strata were themselves folded in conformity with rocks that yielded most readily in the Pre-Cambrian. The writer belives this idea was not sufficiently taken into account by Bailey Willis in his magnificent contribution on the Mechanics of Appalachian Structure.

Throughout the Mid-Continent Oil Field there are areas of folded strata along the flanks of notable uplifts. Most of the oil fields are along the west slope of the Ozark Arch, while others are nearer the Arbuckle Mountains or bordering the Sabine and Burnet disturbances. Many of these local structures take the form of isolated domes or bulged anticlines of relatively small area, but showing a vertical movement that is proportionately strong. The writer takes the view that structures of the type of Healdton, Cushing, Garber, Billings, Augusta, Eldorado, Dexter, Elmdale, Zeandale, etc., were produced by pressures that in the main acted vertically. Probably all of the strata are folded so that if every bed could be stripped off down to the pre-Cambrian, it would be found that the deep-seated crystallines were themselves folded. Care should be made not to confuse this idea with intrusion, but rather to view it as a laccolitic process.

In the uplift of mountains, a deep-seated flowage of rocks takes place so that the basic magmas move laterally to the area of least resistance. In so doing, pressures are set up on the fluid rocks permitting hydraulic forces to act equally in all directions. At places where the total strength of overlying rocks is not competent to withstand this pressure, there is a local buckling of the whole mass. Such a structure may be very local in nature. There is every conceivable gradation of local uplifts from the round saline dome to the elongated bulged anticline. The writer would attribute many of these structures to pressures acting upward from the centrosphere. This idea places them in the category of minor uplifts, whereas the mountains represent the major uplifts. Moreover, in cases of igneous masses that were intruded though the sedimentary rocks, lateral

pressures that folded the parallel zones of anticlines and synclines acted first on the deeply buried rocks that were most susceptible of flowage. In this manner the whole tectonic influence was spread to the outer limits of the area affected.

The practical application of this idea lies in the assumption that our anticlines, domes, etc., do not play out with depth. Well logs testify to the fact that the deeper strata do not show milder structure, but on the other hand are more strongly folded than those at shallower depths.

DISCUSSION

Mr. Taylor.—I would like to ask whether the folding he suggests was done by the granite being forced up, or the sediments merely settling?

Mr. Gardner.—I think it acted as a block to force itself up and bulge the sediments above.

Mr. Wrather.—How does he account for the west dip being greater than the east dip?

Mr. Gardner.—It seems possible in the case of the Ozark uplift that there is a lateral pressure at the same time as the vertical pressure.

Mr. Thomas.—I, regard the discussion of that principle, or theory, one of the most important questions before us in the commercial work of the Mid-Continent field today, and it has been my privilege for something like two years to have private discussions with the author of the paper, and after two years, I do not quite agree with the theories that appeal to him. He avoids Mr. Wrather's point by admitting the other argument, lateral pressure. I would like to ask Mr. McCoy his views.

Mr. McCoy.—I would like to champion Mr. Gardner's cause; the influence is local. I have been considering how far away the lateral stress would have to be applied, to cause a complete anticline in 3,000 feet of limestone. My conclusions are that lateral stress in this thickness of material would never form an anticline more than 10 or 12 miles away from the point of application on account of the tendency of the limestone to crush. So the folds throughout the Mid-Continent oil field must result from stresses which have accumulated locally, that

is, within a few miles laterally of the point of flexure.

Mr. Thomas.—In Northweastern Montana we have a series of 20,000 feet, largely limestone; in one part there is some 10,000 feet of hard limestone. It is hard to explain from a force acting vertically in that tremendous series of limestone, but there is considerable folding and I believe it was largely due to lateral pressures.

Mr. McCoy.—The distance laterally to the point of pressure varies with the character of the material. Large folds are closely associated with general up-lifts or stress from below deforming considerable area. Small folds in a unbroken country are most likely developed by stresses which are set up locally, possibly due to the flow in the softer series of materials while undergoing settling.

Mr. Bloesch.—When Mr. McCoy made his deductions I suppose he started from the pressure taken to crursh a little block of limestone.

Mr. McCoy.—I took the factor of Doctor Adams, namely, the crushing strength of 30,000 lbs. per sq. in. and increased it to 100,000 lbs. to the sq. in., where the rock is reinforced as in the case of deeply buried sediment.

Mr. Bloesch.—The rocks under a big load and a big pressure are plastic, much like clay; as soon as they are like clay the figures will not work any more.

Mr. McCoy.—Plastic rocks would fold sooner than the more rigid rocks. Start with a slab of limestone 3,000 feet thick and apply lateral pressure great enough to crush it entirely at the point of contact. How far out will there be no movement? According to the equilibrium of static friction from the weight only, there will be no movement 9 or 10 miles out and the slab would never slip beyond that point, but fold or crush within ten miles.

THE GRANITES OF KANSAS

By CHARLES H. TAYLOR, *Oklahoma City*

Preliminary Statement

Recent drilling for oil and gas in east central Kansas has revealed the presence of granite at nine different points. The problems presented by the discovery of this granite are of such unusual interest and importance that the writer has decided to present here a brief statement of its occurrence and relations. Much of what is included here was presented in an informal manner at the Norman and Tulsa meetings of the Southwestern Association of Petroleum Geologists. Some new data have been secured even since the Tulsa meeting and the addition of further data which are certain to be secured will, very likely, require the modification of some of the conclusions reached here.

The drill holes which have recently encountered granite in Kansas will all be found in a belt 10 miles wide and extending from the well near Burns, in southern Marion County in a northeasterly direction for 105 miles to Onaga in Pottawatomie County. A list of these wells with some of the more important facts in regard to them will be found on the following pages. So far as the writer can learn no wells to the southward of the Burns well have ever encountered granite, though a number of deep holes have been drilled between Burns and the state line on the south. There have been reports of the striking of granite and quartzite to the north of Onaga but no samples from these wells have been examined by the writer. Judging from personal conversation with geologists who have worked in this area and examined some of the well cuttings the writer does not doubt but that granite has been encountered in some of these wells. The reports of the Kansas Geological Survey tend to strengthen this belief. Since no samples of drill cuttings from these wells have been examined by the writer they will not be included in the discussion.

The sedimentary rocks appearing at the surface in the area under consideration belong to the late Pennsylvanian and early

Permian periods A generalized stratigraphic section of the Cottonwood Falls quadrangle is shown on the accompanying page. The strike of the Ft. Riley limestone from the southern line of the state to Florence, in Chase County, is sligthly west of north, while from Florence to the Nebraska line it is slightly east of north. Taken from one side of the state to the other the strike of the Ft. Riley may be said to be due north-south. The dip, except locally, ranges between 10 and 30 feet to the mile to the westward, with an average of around 20 feet to the mile. If we consider the belt of country 30 miles wide and 150 miles long, extending from Onaga on the northeast to Augusta on the southwest it will include all the wells in which granite has recently been found in Kansas. Within this belt there are a number of elongated folds in which the rocks frequently dip 50 to 100 feet to the mile and in some cases at a much higher rate. Some of these folds, as at Beaumont and the west Augusta fold, are long narrow and symmetrical with very strong east and west dips. In such cases the long axis has a direction of about north 10 degrees east. Other folds are relatively much broader and some are quite irregular in outline.

Wells Showing Granite

Below are given some of the more important facts in regard to the distribution of the wells in which granite has been encountered together with the depth to the granite and the thickness penetrated:

Burns Well: This well is located about three miles southeast of Burns, Marion County, on the Lilly ranch, in sec. 14, T. 23 S., R. 5 E. The mouth of the well has an elevation of 1490 feet. The well starts near the middle of the Ft. Riley Limestone and struck red granite at 2,331 feet. This well was abandoned at 2,500 feet in granite. The complete drillers log will be found on a subsequent page.

Elmdale Well, No 1: This well is located on the county poor farm, one mile south of Elmdale, in sec. 34, T. 23 S., R. 5 E. The elevation at the mouth of the well is 1,185. The well starts near the base of the Elmdale formation, and struck granite at about 1,805 feet. The well was abandoned in granite at 2,500 feet.

Elmdale Well, No. 2: This well was drilled in sec. 2, T. 20 S., R. 7 E., two miles southeast of Elmdale, Chase county.

Elevation 1,400 feet. The well starts in the Garrison formation. Granite was encountered at 1,873 feet and, excepting 60 feet of basic igneous rock, drilled in granite to 3068 feet where it was abandoned.

Hymer Well: The Hymer well is located in sec. 34, T. 18 S., R. 7 E., in southern Morris county. The well starts near the top of the Florence Flint at an elevation of 1,500 feet. Granite was found at 2,505 feet depth and the well was abandoned in granite at 2,608 feet.

Kelso Well: This well is located two miles south of Kelso, in sec. 24, T. 15 S., R. 7 E., Morris county. The well starts at about 1,325 feet elevation in the Matfield shale. Granite was found at 2,230 and the well was abandoned in granite at 2,500 feet.

Zeandale Well No. 1: The first well drilled at Zeandale was located in sec. 28, T. 10 S., R. 9 E., just south of the town. It starts in the Eskridge shale at an elevation of 1,050 feet. Granite was found at 928 feet and the well was abandoned in granite at 1,020 feet depth.

Zeandale Well, No. 2: The second Zeandale well was located in sec. 26 to the east of No. 1. It starts in the Elmdale formation at 1,050 feet elevation. Granite was encountered at 942 feet and the well abandoned at 1,020 feet depth.

Waubunsee Well: This well is located in sec. 1, T. 11 S., R. 9 E., in Waubunsee county. The well starts in the Eskridge shale at an elevation of about 1,125 feet. Granite was encountered at 1,175 feet depth and the drill was stopped in granite at 1985 feet depth.

Onaga Well: The Onaga well is located in sec. 34, T. 6 S., R. 11 E., in the town of Onaga, Pottawatomie county. The well starts in the Elmdale formation, at an elevation of about 1,100 feet. Granite was encountered at 906 feet and the well was stopped in granite at 1,720 feet depth.

So far as the writer can learn these are all the wells in the territory outlined that have without question, been drilled into granite. Reports seem to indicate that a well in the town of Strong was drilled into granite, but no cuttings were available and it is therefore omitted from the list.

A number of other deep wells have been drilled within this area which have not encountered granite. The most inter-

esting example of this is the well east of Burns, in sec. 34, on the Barker farm. This well is one half mile west and two and one half miles north of the Lilly well. It starts near the top of the Winfield Limestone, at an elevation of 1,500 feet, and was drilled to a depth of 3,112 feet without encountering granite. Another somewhat less striking example is the Alta Vista well, located in sec. 9, T. 13, R. 8. This well starts at about 1,450 feet elevation and was drilled to a depth of 2,760 feet without finding granite. The distance of this well from the Waubunsee well is about 15 miles, while it is about 19 miles from the Zeandale wells. This shows the granite to be more than 1,260 feet higher in the Waubunsee well than in the Alta Vista well while in the Zeandale wells the granite is more than 1,400 feet higher than it is 19 miles away in the Alta Vista well.

The Granite.

There has been much speculation and some controversy among the active geologists of the southwest as to the true character of the rocks encountered in some of the wells listed above. The writer has had the privilege of examining drill cuttings or hand samples from all of these wells excepting the Kelso well. Mr. R. A. Conkling, head geologist for the Roxana Petroleum Company has furnished the data for this well.*

Thin sections were made from a sample obtained from one of the Zeandale wells and under the petrographic microscope showed normal granitic texture and the following minerals named in the order of abundance: Quartz, microcline, orthoclase, biotite, muscovite, zircon, and secondary chlorite, kaolin and hematite. The feldspars were little altered to kaolin or other secondary minerals and under the microscope appeared quite transparent.

Some fragments of the granite from the Burns well almost a centimeter in area showed very clearly the interlocking crystals of flesh colored feldspar and glassy quartz. There can be

*The writer is indebted to Mr. E. Z. Carpenter and Mr. Roy S. Hazeltine, geologists for the Empire Fuel and Gas Company, for the privilege of examining the drill cuttings from the four wells which that company has drilled into granite.

no question about this being a sample of a medium grained granite not unlike the granites found so abundantly in Oklahoma and the surrounding states.

Samples of the drill cuttings from the two Elmdale wells were examined under the petrographic microscope and showed fresh transparent orthoclase in abundance, a small amount of plagioclase, and quartz. In all the samples the quartz is less abundant than the feldspar. Examination of these samples under the binocular showed the feldspar to be so nearly transparent as to be distinguishable from the quartz with difficulty.

Drill cuttings from No. 2 Elmdale well disclosed about 60 feet of a dark fine grained rock, apparently a diabase or diorite. Small quantities of a similar rock were encountered in some of the other wells according to the drillers.

Structural Relations of the Granite.

The presence of granite in the deep wells in Kansas being now quite generally accepted, the most important problem for consideration is the relation of this granite to the sedimentary rocks of that area. If this granite is an intrusive and reached its present position and relations subsequtnt to the deposition of the overlying sediments one would look for considerable folding and probably faulting of the intruded sedimentary rocks. If the intrusive were large there should be considerable hydrothermal metamorphism. On the other hand if the sedimentary rocks were laid down around and over large masses of igneous rocks quite different relations would prevail. An increase of clastic sediments, with probably conglomerates, should be observed as the granite is approached, and these sediments may incorporate fragments of weathered granite. Drill cuttings from the outer portion of the granite mass may show the effects of weathering which will diminish with depth. Ancient weathering, however, may be difficult to distinguish from the chemical effect of circulating ground water.

The data so far obtained would seem to exclude the intrusion theory. No faults of consequence are known in this area. The strata are somewhat folded but the folding may take place in the absence of igneous intrusion equally as well as with it. No evidence of contact metamorphism has ever been detected. The logs examined showed normal shales, sands and

limestones immediately above the granite. The unindurated condition of the overlying shale has been used as an argument against the presence of granite in the Zeandale wells.*

Small masses or dikes of igneous rock may be intruded without apparent deformation or metamorphic effects, and when the granite was first found in this area this explanation of its presence was given. This view is clearly untenable at the present tiem. The ingeous mass whatever its origin is of large dimensions. This is proven by the wide distribution of the wells encountering granite, together with the great thickness of granite penetrated. This may be seen from the situation at Elmdale. Well No. 1 penetrated nearly 700 feet of granite and well No. 2, 2 miles east, encountered the granite 140 feet higher and penetrated 1,195 feet of it. The Hymer well, twelve miles due north, found the granite at 2,500 feet and penetrated 103 feet of it. The three wells stopped in granite. Such a condition is obviously impossible if the granite is in the form of thin dikes or small masses.

Though the evidence supporting the theory that the granite is a part of an old land mass is not as definite and conclusive as could be wished, the writer believes this theory more tenable than any other. An examination of the well logs found on a subsequent page reveals the fact that there is much more sandstone below 2,500 feet than there is above that point. This condition is noticeable throughout this part of Kansas where deep wells have been drilled. In the Elmdale No. 1, pebbly sand was reported immediately above the granite. In the Hymer well Mr. R. A. Conkling states as follows: "At about 2,000 feet 30 to 40 feet of sand and gravel was gone through. In this we got chert boulders 2 inches in diameter, and quartz pebbles one-fourth to three-eighths inch in diameter." All of the sands from immediately above the granite that the writer has examined were decidedly free from pebbles. A small sample of red shale from a few feet above the granite in the Burns well contained some very small fragments of flesh colored feldspar and possibly a few fragments of quartz. In the Kelso well there was a considerable thickness of limestone above the granite and below

*The Crystalline Rocks of Kansas. Kansas Geological Survey Bulletin, 1915.

the pebbly sand so that it was in no sense a residual from the granite mass.

All of the samples studied show a variation in the color of the granite from its upper surface downward for a hundred feet or so. This change in color seems to represent very clearly the change which takes place in the surface weathering of a granite. The first samples from some of the wells had a granular appearance characteristic of some weathered granites. The first sample from the Burns well would easily be classed as medium grained, some of the feldspar crystals being at least five millimeters in diameter. In none of the wells was there a suggestion of a glassy or fine grained margin and in no case was there a suggestion of coarser texture with depth, such as might be revealed if the granite were intruded into the sediments.

The topography of the granite mass so far as it has been determined is that of mountainous area with jagged peaks projecting above the general elevation of the region. Slopes of more than three hundred feet per mile have been determined. It will be noted also from the Zeandale area that there are relatively high level areas, plateau like in character. In this area the granite lies above the present sea level. The elevation of the granite mass appears to increase to the northward. The Onaga well found the granite about 200 feet above sea level and the reports of granite farther north seem to indicate it continues to rise in that direction. In the Eldorado field about 15 miles south of the Burns well a 3,600 foot well failed to reach granite and a number of other wells 2,800 to 3,000 feet deep have failed to reach it.

The relation of the higher granite masses to the structure of the rocks at the surface is of some interest. Of the four deep wells drilled on the Burns structure only one and that the shallowest of the four, found granite. The three wells which did not encounter granite were drilled from 125 to 200 feet down from the crest of the fold while the one which did encounter the granite was not over 45 feet below the crest of the anticline. It will be interesting to note if future wells drilled on the crest of this fold get the granite at even less depth. At Elmdale both wells were on the fold but the one nearest the crest of the fold got the granite the highest, while

the Hymer well drilled on a fold having a lower apex than the Elmdale fold got the granite lower than either of the Elmdale wells.

The Zeandale, Waubunsee and Onaga wells are all on broad folds and found the granite higher than in the wells in the surrounding region farther from the crest of the folds. The Alta Vista well was drilled on a structure but failed to strike granite at much greater depth than it had been encountered in some of the other nearby wells on other folds. At the Tulsa meeting the writer made the statement that the Zeandale wells were not on structure and through the kindness of Mr. Harve Loomis, has since learned that he was in error in this statement. The Zeandale wells are a considerable distance west of the crest of a broad fold with a gentle west dip, and should in a strict sense be considered on an anticlinal fold.

To summarize the situation; it appears that the granite so far encountered has been found invariably under surface folds, though in some cases the wells were drilled a considerable distance from the crests of these folds. In two cases, Burns and Elmdale, the granite appears to be the highest under the crests of the folds, though further drilling will be required to determine if this is strictly true.

Age of the Granite

There is now but little evidence pointing either to the age of the granite or the time when it came into its present position. The 3,600 foot hole in the Eldorado field seems to show that the Mississippian is well developed in that area. The presence of a cherty conglomerate at 2,000 feet in the Kelso well also suggests that the Mississippian or earlier siliceous sediments may have been subjected to erosion during early Pennsylvanian or late Mississippian time. The general absence of anything like Mississippian rocks overlying the granite where found, and the presence of apparent normal Pennsylvanian sediments well down the granite slopes all seem to point to the presence of considerable areas of exposed granite in the early Pennsylvanian time. If the Mississippian sediments once covered these granite masses, which is suggested though not proven by any means, then there must have been rather intense though local deformation during the latter part of the Mississippian or the early part of the Pennsylvanian period. Following this deformation these folds were rapidly truncated thereby sup-

plying the sands which are so abundant in the lower Pennsylvanian in this area. It was about this time that the Mississippian limestones were exposed to erosion in southeastern Kansas. It was also about this time that local though intense deformation was taking place in the Arbuckle and Wichita mountains, Oklahoma.

The writer has observed in the well logs of the Augusta field a rather unusual abundance of limy and sandy sediments which appear to be intimately intermixed. Such sediments are unusual and must have been laid down under local and unusual conditions. If there were local areas of deformation and erosion surrounded by open sea, we may find the required conditions for the accumulation of the sandy limestone in the waters not far distant from the uplifted area. The areas favorable for the accumulation of the sandy lime sediments seem also, especially in the Augusta field, to have been favorable to the accumulation of oil forming materials. The absence of the sandy lime and sand sediments in the upper 2,000 feet of the logs would be due to the submergence of the greater part of the exposed granite mass.

Generalized Stratigraphic Section for the Cotton wood Falls Quadrangle (from the Cottonwood Falls folio).

Formation	Thickness ft.	Character
PERMIAN		
Marion Formation	150	thin limestones and shales
Winfield Limestone	20-25	limestone and shale, chert at the base
Doyle Shale	60	green shale
Ft. Riley Limestone	40	thick and thin bedded white limestone
Florence Flint	20	cherty limestone
Matfield Shale	60-70	shale and thin limestone
Wreford Limestone	40	massive cherty limestone
PENNSYLVANIAN		
Garrison Formation	140-145	shale with thin limestone
Cottonwood Limestone	6	massive limestone
Eskridge Shale	30-40	shale and thin limestone
Neva Limestone	10	massive limestone
Elmdale Formation	130	blue and gray shale and thin limestone

Log of well on Lilly ranch sec. 14, T. 23, S, R. 5 E., three miles southeast of Burns, Kansas.

	Thickness feet	Depth feet
Hard Lime	45	45
Sand	5	50
Blue Shale	10	60
Hard Lime	30	90
Blue Clay	30	120
Shale	10	130
Sandy Shale	16	146
Blue Slate	5	151
Red Rock	5	156
Blue Lime	15	171
Slate	19	190
Blue Clay	20	210
Shell	6	216
Sandy Lime, water	14	230
Blue Slate	5	235
Blue Lime	10	245
Slate	7	252
Clay	40	292
Red Clay	22	314
Lime	10	324
Slate	18	342
Blue Clay	20	362
Shell	3	365
Brown Clay	12	377
Blue Lime	13	390
Blue Clay	165	555
Lime Shell	10	565
Blue Clay	50	615
Sand, Water	7	622
Blue Shale	108	730
White Lime	6	736
Gray Shale	49	805
Lime	15	820
Blue Shale	150	970
White Sand, much water	15	985
Lime	5	990

	Thickness feet	Depth feet
Brown Shale	20	1010
Lime	15	1025
Black Shale	38	1063
Lime	2	1065
Shale	30	1095
Lime	5	1100
Shale	5	1105
Lime	20	1125
Shale	40	1165
White Shale	5	1170
Lime	20	1190
Shale	5	1195
Gray Lime	75	1270
Shale	15	1285
Lime	65	1350
White Sand, water	20	1370
Shale	60	1430
Sand	10	1440
Lime	6	1446
Sand and Shale, much water	14	1460
Black Shale	50	1510
Lime	10	1520
Blue Shale	10	1530
White Sand	10	1540
Hard Lime	20	1560
Black Shale	45	1605
Hard White Lime, water	48	1653
Black Shale	4	1657
White Lime	90	1747
Blue Shale	103	1850
Lime	30	1880
White Sandy Shale	13	1893
Lime	22	1915
White Shale	15	1930
Lime	12	1942
Lime	48	1990
Sandy Lime	10	2000
Shale	12	2012

	Thickness feet	Depth feet
Sandy Lime, water	10	2022
Shale	22	2044
White Sand, much water	20	2064
Lime	26	2090
Slate	5	2095
Red Mud	5	2100
Shale	15	2115
Lime	5	2120
Shale	40	2160
Sand	20	2180
Lime	40	2220
Shale	10	2230
Sand, show of oil, much water	30	2260
Broken Lime	37	2297
Slate	10	2307
Lime	5	2312
Sand (Granite?) much water,	14	2326
Mud	5	2331
Red Granite	55	2386
Break	4	2390
Red Granite	110	2500

Log of well on Barker farm, sec. 15, T. 22 S., R. 5 E., one mile east of the town of Burns, Kansas.

	Thickness feet	Depth feet
Broken Lime	150	150
Slate	35	185
Sand, hole full of water	15	200
Slate	15	215
Lime	30	245
Slate	50	295
Lime	25	320
Slate	17	337
Lime	18	355
Slate	45	400
Lime	5	405

	Thickness feet	Depth feet
Slate	15	420
Sandy Lime	15	435
Slate	15	450
Red Rock	8	458
Lime	5	463
Blue Slate	15	478
Slate	12	490
Blue Slate	30	520
Light Slate	5	525
Sandy Lime	15	540
Light Slate	28	568
Lime	22	590
Blue Slate	70	660
Lime Shell	5	665
Slate	25	690
Lime	10	700
Slate	30	730
Red Rock	10	740
Lime	10	750
Slate	165	915
Lime	10	925
Slate	31	956
Lime	23	979
Slate	56	1035
Lime, water	10	1045
Slate	35	1080
Sand	10	1090
Slate	40	1130
Hard Lime	15	1145
Black Shale	50	1195
Lime	40	1235
Slate	5	1240
Lime, water	30	1270
Slate	10	1280
Lime	35	1315
Slate	10	1325
Lime	10	1335
Slate	10	1345

	Thickness feet	Depth feet
Hard Lime	40	1385
Slate	25	1410
Lime	10	1420
Black Slate	10	1430
Lime	30	1460
Slate	49	1509
Lime	30	1539
Black Slate	6	1545
Lime	6	1551
Slate	79	1630
Sand, much water	30	1660
Slate	40	1700
Lime	8	1708
Slate	7	1715
Hard Lime	20	1735
Sand, water	12	1747
Slate	76	1823
Lime water	12	1835
Shale	5	1840
Lime, much water	102	1942
Shale	130	2072
Lime	6	2078
Black Slate	2	2080
Lime	12	2092
Brown Slate	8	2100
Very Hard Lime	90	2190
Slate	5	2195
Lime	5	2200
Slate	5	2205
Lime	5	2210
Slate ,much water	80	2290
Lime	20	2310
White Slate	20	2330
Lime	15	2345
Slate	30	2375
Lime	5	2380
Slate	105	2485
Sandy Lime, water	53	2538

	Thickness feet	Depth feet
Black Slate	92	2632
Lime	3	2635
Brown Shale	15	2650
Lime and Sand, much water	40	2690
White Slate	4	2694
Water Sand	46	2740
Sand	75	2815
Lime	70	2885
White Sand	20	2905
Lime	60	2965
White Sand	45	3010
Lime	62	3072
White Sand	40	3112

DISCUSSION

Mr. Wrather.—We have practically the same thing in Texas, excepting the old core of granite. The core is Mississippian or Pennsylvanian and is covered with Pennsylvanian sediments with pronounced structure in the Pennsylvanian. It had, perhaps, the same sequence of events as in Kansas, except it probably was not so complete.

Mr. Loomis.—I would like to ask if any one present has ever found granite in wells not on structure.

Mr. Thomas.—Granite has been discovered five miles northeast of Inola, Oklahoma, and not associated with any folding so far as I know.

Mr. Moore.—Before leaving the discussion of the granites of Kansas, I want to say a few words in regard to the situation so far as it goes in my cognizance. Dr. Haines, member of State Geological Survey of Kansas, has taken the problem of the granites of Kansas very definitely under consideration, and from field work and from the records so far as we have them, is endeavoring to get at the root of the matter. I speak of that so that all of you who have had a definite field acquaintance with the material, will get in touch with us. We hope to give the matter the attention it really deserves. We will greatly appreciate any information which comes from the geologists.

The second point I wish to make is, examination of the old

deep well logs in the office shows apparently the existence of granite at varying depths, which was misinterpreted at the time of the examination of the well logs. There is no doubt whatever, on examination of the cuttings that the material penetrated was granite, whether Ordovician or fresh granite, is to be determined, but masses of considerable quantity of feldspar have been reported in areas northeast from Pottawatomie county. We hope a study of the whole field will show a variation of the old land surface and enable us, as new records and the cuttings of the completed wells come in, to block out with greater accuracy the situation.

It is our hope on the Survey, by careful correlation of the strata in the Mississippian and Pennsylvanian and other formations concerned, to trace them out as far as possible and see what the connection with this granite has been. The chief difficulty has been that accurate well logs in this vicinity are not at present available, so co-operation in this study will be appreciated. So far as Kansas is concerned we can assert that there is crystalline rock in our back yard.

HINTS TO PROSPECTIVE GEOLOGISTS.

By J. A. UDDEN, *Austin, Texas*

(Norman meeting, January, 1916.)

To give good advice to young men who are ready to enter a professional career is a delicate task. I think this is especially true in the case of young men who are preparing for the geological profession. Probably no two men need the same advice. The subjective differences of the human mind are great. We are also at the period in the development of the geological profession when a rapid and fundamental change is taking place, not only with regard to what is considered proper training for the profession, but also in regard to the nature of the professional work to be performed. Geologists of fifty years ago were mainly concerned with problems connected with scientific truth. Today, we are all more or less interested in the application of such truths to the development of some useful industry.

Probably the greater number of the earlier geologists of half a century ago were more or less self-taught. There were at the time few universities offering courses of study in geology. The early investigators in geological science in America had their first and only training in the field and in such libraries as were available, or such as they could collect. I presume there will always be some geologists who will be chiefly self-taught; but I think it is true of the large majority of geologists today, that they have had university training under professional teachers, and I presume this will be more or less true for all time to come. This fact should discourage no one to pursue the science independently. After all, the only true knowledge of nature comes through the study of nature itself, and in all ages, there have been men who, without special instruction from others, have been able to acquire profound insight into Nature's secrets. Geology is nothing but the sum of information which has been acquired by a great number of workers in the last cen-

tury, with regard to how the earth's exterior has been made and with regard to the changes that it has undergone in the past. The quickest and easiest way to acquire this general knowledge is no doubt by attending instruction in the science of geology at learned institutions. Such preparation most of our young geologists now possess, I am glad to know.

If I were to give one item of advice to geologists who have no such preparation, it would be that they should mistrust all the facts that they think they have observed. And if I should give a single item of advice to graduates from geological schools, it would be that they should mistrust their own understanding of what has been taught them. A college course, and even a university course, in geology, is at the best a brief rehearsal of the generally established outlines of the science. Every little local problem which may be of the greatest importance in any particular work of a professional geologist, is certain to bring up a great many things never discussed in the textbooks, or even in the lectures in a university. A young geologist who attempts to adjust all of his observations to theories or to valid rules which he has learned from a teacher, will be certain to come to grief. On the whole, in most cases I believe the advice most needed by graduate students in geology who have entered the geological profession, is to rely on their own judgment, on the dictates of their own common sense, irrespective of the knowledge they may have acquired as students.

To give advice is, in one sense, easy enough; to follow it is more difficult. I presume that the practice is quite general for professional geologists to secure all the information possible on any region they expect to examine, before seeing it. This has been my own practice. It not only aids in making observations, but it should be a help in making correct interpretations of facts noted. I think it equally important to consult all recorded opinions and observations made by others on a region that we have examined, after we are through making our own observations. This practice is very general. In fact, a geologist's standing in his profession is, to some extent, determined by the amount of attention he has given to the work of others on the subjects which he himself investigates. I know of one prominent geologist who never likes to read much of what others have said concerning a region where he wishes to make his own observa-

tions. He believes that in this manner he approaches his own study in a more impartial attitude, unbiased by the opinions of others. I have no doubt that for some this practice may produce the best results. Independence of action is always to be desired in the exposition of truth.

One piece of advice which I shall give is against the fear of criticism. My belief is that the professional geologists of America have been subject to too little criticism. They have not encouraged it. One reason for this state of affairs is no doubt the somewhat precarious condition of the profession itself, and perhaps this fact to some extent is an excuse for the condition. To outsiders, criticism of a professional man reflects, as it were, on the profession. This is not at all the case, as we all well know. Geologists, like men of other professions, ought to mercilessly criticise each other within their own circle, when occasion arises. But they should defend each other before the public at large. Any man may make a mistake. I believe that this professional sense, or comity, is beginning to develop at the present time. It is justified by the conditions we so well know and understand. No one who has watched the reckless expenditure of energy and money, private and public, by people ignorant of the simplest facts known to the geological profession, can fail to realize the great good that would come to the public at large, if scientific advice were more generally considered and heeded than it has been in the past. Quite recently a case came to my attention where some $20,000 had been uselessly spent on the strength of incompetent advice. It involved the identification of a certain formation, by a party absolutely innocent of all knowledge requisite for advising on the problem presented. No one can know better than we do ourselves, the benefit that would accrue to the public from an increase in the number of able members of our own profession and from an increase of faith in our profession on the part of the public. This condition should prompt us to a greater loyalty to each other.

It seems that we all, young and old, need the admonition to at all times perform our work thoroughly. Extensive observations must be the basis of all good work. The greater the basis of observation, the more conclusive the deductions which we can make. No geologist should limit his observations to noticing things such as are already known to be worthy of at-

tention. Always we should strive to make observations of things which no one else has previously noted; little things and great things that are new. We should set forth with the idea that there is nothing too small or too simple to have an important bearing on the problem in hand. There is no doubt in my mind that the future geologists will consider as important many things which receive no attention from geologists of today. Thus, it seems to me that we have very little definite knowledge on many fundamental facts with regard to the history of the making of sedimentary rocks. Still less do we know about the minor changes which have taken place in these rocks long after they were laid down.

I have limited my brief remarks to the practice of those cardinal virtues for which we all strive—the common-place good qualities which a professional man should possess. Let me finish by calling your attention to another equally self-evident virtue on the part of a consulting geologist. I believe that it will greatly enhance the public estimate of our profession of consulting geologists if we shall be frank in acknowledging ignorance where knowledge is impossible, or not attained. The practice of ornamenting the truth by indulging in extravagant circumlocutory generalizations should be avoided. A frank statement of what might be desired to know, but impossible to find out, in any particular case, will disgrace no one; and it will, in the long run, contribute to the coming of the time when the public will readily be able to distinguish between the real scientist and the charlatan.

AN OUTLINE FOR A TYPE REPORT ON AN OIL FIELD.

By W. C. Kite, *Perry, Oklahoma*

(Norman meeting, January, 1916.)

(Note: There is great need for close detailed work by the geologist in producing oil fields, and the following is an attempted outline for a report on such a field. However as most reports at present are required on "wildcat" territory, the outline may be modified to fit such report by merely omitting much of Section VI.)

I. Location of Area.

State, county, in some cases sections, ranges and townships. Railroads.

II. Physiography.

(Brief statement)

III. Stratigraphy.

A. A geologic section of formations as complete as possible from exposed rock and well logs.

(a) Thickness, character, age and stratigraphic relations of the formations.

(b) Producing horizons and sands.

IV. Structure.

A. General statement of structure with reference to character and extent. Here make reference to contour map.

(a) Normal dip of country.

(b) Structure of field.

B. Instruments and methods used in determining structure.

(a) Horizon markers at surface and in well logs.

C. Dips.

(a) Directions, and amounts in degrees.

D. Faults.

E. Comparison of underground structure with surface structure.

(Map: (a) Contour map of surface structure, (b) Contour map of underground structure, (c) Show all wells by symbols. These maps should be on horizontal and vertical scale suitable to show adequately the relations of production to structure.)

V. Surface Indications such as gas and oil seeps.

VI. Development.

A. Brief history of field, giving, first locations, name of company, depth, production, and life of wells.

B. Wells.

(a) Number drilled in field up to time of report.
(b) General statement of location of wells in relation to structure.
(c) Number producing and number dry.
(d) Maximum initial production, natural, after shooting.
(e) Average initial production, natural, after shooting.
(f) Depth, thickness, name and number of sands and production of each.
(g) Gas found, amount and relation to production and structure.
(h) Water found, depth, quantity, and relation to structure.

C. Drilling.

(a) Rigs and tools used.
(b) Size of hole.
(c) Strings of casing used.
(d) Rate of drilling.
(e) Fuel and water.
(f) Wages and cost of drilling.

D. Oil.

(a) Gravity.
(b) Color, by reflected and transmitted light.
(c) Viscosity.

(d) Flash point.
(e) Base.
(f) Analysis.

E. Marketing.
(a) Pipe lines.
(b) Railroads.
(c) Price.
(d) Refineries.
(e) Uses.

F. Production of field.
(a) Total to date.
(b) Present daily production.
(c) Past daily production.
(d) Number of wells producing.

G. Leases. (Brief statement of terms including bonus and royalties paid.)

VII. Summary.

NORTH-SOUTH CORRELATION OF THE PENNSYLVANIAN OF OKLAHOMA.

By EDWARD BLOESCH, *Tulsa, Oklahoma*

(Norman meeting, January, 1917.)

The geologists working in Oklahoma have all felt the necessity of a correlation of the areas mapped in detail in the South (the Coalgate, Oklahoma, folio) and the one in the North (the Independence, Kansas, folio) which has been extended by D. W. Ohern as far south as the Arkansas River.

As early as 1910 a tentative correlation had been established by Chas. N. Gould, D. W. Ohern, and L. L. Hutchison[1], at the same time dividing the Pennsylvanian into groups. This was done on the rather meager information available at the time, as a basis for future work. I have had an opportunity to make a number of observations which may throw some light on the subject.

Between the Muskogee and the Tulsa groups is the Claremore formation (the Fort Scott of the Kansas section) which is supposed to be the equivalent of the Calvin sandstone as used in the Coalgate folio. My observations show that the top ledge of the Calvin is probably the same as the sandstone on which the town of Weleetka is built, which in turn corresponds with the Two Twins (Bald Hill) northeast of Okmulgee, and this is the same as the sandstone member of the Claremore formation. This formation as a whole is not, however, very suitable for correlation purposes, as it shows a remarkable thickening southward, and the top of it is probably to be found in the Wewoka formation.

The Checkerboard limestone of the Tulsa-Glenn Pool area forms the boundary between the Tulsa and the Sapulpa groups, and has been tentatively correlated with a limestone that out-

---

[1]State University of Oklahoma, Research Bulletin No. 3.

crops at Holdenville in the Holdenville shales. The equivalent of the Checkerboard, however, is further west in the Seminole Hills. I have found limestone in several places east of Okemah at about the horizon where the Holdenville limestone should be. At Beggs there are two limestone ledges below the Checkerboard. This horizon extends north, across the Arkansas River, where limestone belonging to the Nowata formation is known in the hills southeast of Tulsa. The limestone east of Okemah is evidently the lower one of the two at Beggs. It is not known that one continuous limestone formation extends all the way from Holdenville to Tulsa, but the different outcrops observed are apparently at the same horizon. This is evidenced by the continuity of the pronounced sandstone escarpments above and below. The one below forms the top of the Wewoka formation (Coalgate folio). It has been traced northward where it evidently grades into the Labette shales. The lowest ledge of the Seminole conglomerate can be traced northward, partly as a conglomerate, partly as a sandstone. In the 1000 foot hill four miles east of Okemah the conglomerate is typically developed. Following it further north the flint pebbles get smaller and smaller until west of Beggs they are not much larger than the head of a pin. I have noticed at about the same horizon in the Nowata formation north of the Arkansas River conglomeratic layers, but this conglomerate is of a different origin.

My observations allow me to say that the Holdenville formation (Coalgate folio) is in a general way, the equivalent of the Nowata formation north of the Arkansas River. The Holdenville, however, includes the Oologah formation[2] and probably the upper part of the Labette shales. On the other hand, the Nowata formation includes the Seminole Conglomerate.

I may add that the Pawhuska formation, dividing the Sapulpa and Ralston groups, and well known in the Cushing oil field, has been followed south beyond the town of Paden.

---

[2]This formation consists of heavy limestone north of the Arkansas River, but cannot be distinguished south of the river as nothing but shales are present.

OBSERVATIONS ON POST-PERMIAN DEPOSITS IN NORTH-CENTRAL OKLAHOMA.

By EDWARD BLOESCH, *Tulsa, Oklahoma*

(Tulsa meeting, February, 1917.)

While studying the structural geology of Garfield and surrounding counties in north-central Oklahoma, my attention was drawn to the Post-Permian deposits which conceal in many places the underlying Permian. I made a few observations which may be of general interest.

The Tertiary of northwest Oklahoma has been known for some time, and was fully described first by C. N. Gould.[1] A. T. Schwennesen[2] describes some Tertiary sands and gravels close to Enid. A deposit of such material also caps Red Hill west of Medford. Further to the east, I noticed in several places some gravel at high elevations, for instance, between Billings and Lucien. These are remnants of the former Tertiary cover.

The surface of the higher parts of this country is level, particularly around Garber, also northeast of Billings, in the vicinity of Douglas, Enid, Breckenridge, around Blackwell, and at numerous other places. It consists of a grey sandy soil and the Permian red beds are to be seen only along the channels of the creeks. I consider these high plains as parts of the pre-Tertiary (or possibly per-Cretaceous,) peneplain, and the sandy soil is a last relic of the Tertiary. Unfortunately, no topographic maps are available to check up the elevation of different parts of this probable peneplain.

The Tertiary has probably formed at one time a continuous cover as far east as a line through Crescent, Perry and New-

[1]U. S. G. S. Water Supply Paper No. 148.
[2]U. S. G. S. Water Supply Paper No. 345.

kirk. Further east all the higher hills are formed by strata of Permian and Pennsylvanian age and evidence of Tertiary deposits has yet to be found.

I noticed at different places in this territory and at different elevations angular boulders of varying sizes, some as much as one foot in diameter. They are of flint or cherty material and have a slick surface due to wind polish. Their origin, age and manner of deposition is an unsolved problem.

A bed of volcanic ash about two feet thick was observed in the northwest part of Section 6, Township 19 North, Range 4 West, which is not shown in Oklahoma Geological Survey Bulletin No. 13. The age of the volcanic ash deposits in Oklahoma is not exactly known, but it must be Quarternary, as some of them, like the one north of Wetumka, are down in the valleys and were laid down after the present valleys had been eroded to a considerable extent.

The geological maps of Oklahoma show big areas covered with loose sand, in the western part of the state, as the "Sand Hills." These "Sand Hills" are regular dunes deposited by the wind. Their formation may have started right after Tertiary times and is still going on. They are generally on the north bank of the major streams, while the south side is mostly free from sand. While best developed in the west part of the state where there is not much timber to break the wind, they are noticeable some distance further east, to the annoyance of the geologists looking for future oil fields. Along the railroad from Tulsa to Osage small sand dunes can be seen in different places. On the Muskogee folio[1] wind deposited sands are included in the Terrace sand.

Local gravel deposits associated with this sand can be explained in the western territory, for instance, south of Ringwood, as remnants of Tertiary. In the east part of the state, however, they indicate that part of this sand belongs to Quarternary terraces.

---

[1]U. S. G. S. Folio No. 132.

The material forming the sand hills is of different origin[2], a small part is sand derived from disintegrated sandstones and transported by the wind. Another part of the sand has been carried into this territory by the rivers coming from the country to the west. A third part, which is considerable, is derived from nearby deposits of Tertiary sands, particularly, the material of the sand hills around Enid can only be derived from the Tertiary, as no rivers are in the vicinity which could have carried the sand.

Alluvial (Pleistocene) terrace gravels are present in this territory and are well developed along the valleys of Black Bear, Red Rock, and Deer creeks. Only one terrace seems to be present or at least only one is well developed, while in other parts of the country as much as three different terraces can be discerned (for instance near Colony, Kansas.)

The material of this terrace is very much the same as the Tertiary gravel and it is evidently in its greater part derived from Tertiary deposits. This is in opposition to the terrace gravels further east, for instance along Caney River, which are composed of flint from the Kansas Flint Hills.

In the southeast part of Section 14, Township 26 North, Range 2 West, on Deer Creek, I found a fossil bone which by its state of preservation shows the terrace to be of Diluvial Age (Recent.) It is too fragmentary to be determined but must have belonged to a big animal, presumably *Elephas*.

Another discovery of interest was the right tibia of a coyote (*Canis latrans*) found in the gravel beds, the fill of an old creek in the northwest quarter of Section 9, Township 19 North, Range 6 West. This gravel, which is mixed with some clay and sand, consists of small pebbles, a good part being the lime concretions well known in weathered Red Beds; then sandstone gypsum, shale derived from the Red Beds, some chert and a few quartz pebbles of Tertiary origin. Only the latter are well rounded. This gravel bed rests on Red Beds and attains a thickness of two feet. It is an alluvial terrace but not quite Recent, as the creek in its present stage would not deposit at this level.

---

[2]Gould, Leoc. Cit.

The following fauna has been collected:*

Planorbis dilatatus?
Physa sp.
Unio Macrodon?
Canis latrans?
Undeterminable bones and teeth fragments.

This gravel bed is covered with a sandy loam which may be a continuation of it or may have been washed down very recently from nearby higher levels. It contains the same Mollusca as the gravel and at one place where it rests directly on the Red Beds I found in it bones of what is probably *Bison Americanus.*

The above mentioned observations show that the Post-Permian deposits of north-central Oklahoma are of considerable interest and a complete study, particularly of the Quarternary of Oklahoma and Kansas, should bring some important scientific results.

---

*Determinations through courtesy of Dr. M. G. Mehl.

SOME EFFECTS OF CAPILLARITY ON OIL ACCUMULATION.

By A. W. McCoy, *Ponca City, Oklahoma* .

(Norman meeting, January, 1916.)

All rocks in the upper crust of the earth contain pore space. The percentage by volume of this space varies from a fraction of 1 per cent in the case of most fresh crystalline rocks[1] up to 40 per cent in some sandstones.[2] Below ground-water level these openings are more or less saturated with water, which moves about from points of higher to points of lower pressure.

The movement of water thus entombed does not exactly follow hydrostatic laws, as can be observed by the small loss of head in artesian flow. For example, an instance is cited by Van Hise[3] where water traveled under ground 150 kilometers with a loss of only 50 m. in head. This shows that the movement was very slow (perhaps a few feet per year), for the friction through the porous stratum was almost nothing. In the case of water moving in large openings, such as pipes, friction is an important factor. A somewhat similar example was observed by the author in Missouri, where the loss of head by flow in the Roubidoux sandstone was about 200 ft. in 75 miles. A theoretical means of comparison with the observed facts is to note the size of the openings in the rocks. All tubular openings less than 0.508 mm.[4] are capillary. Therefore, by geometrical proof, it can be shown that sandstones with uniform rounded grains of less than 2 mm. in diameter, would contain mainly capillary openings. Rocks with uniform rounded grains, regardless of the size of grain, contain about the same amount of pore space,

[1]Van Hise, *Monograph,* U. S. G. S. 47, p. 125.

[2]G. P. Merril, *Rocks, Rock-Weathering and Soils,* p. 198.

[3]*Monograph,* U. S. G. S. 47, p. 587.

[4]Alfred Daniell, *Text Book of Physics,* p. 315.

and this is greater than in rocks which have varying-sized and angular grains. Most rocks are made up of particles irregular in shape and less than 2 mm. in diameter, consequently the movement of underground water must be greatly affected by capillary action, *and evidently the forces of static capillarity must be overbalanced before movement can take place.* For that reason a discussion of Poiseuille's law of flow in capillary tubes has been omitted, and the conditions of static capillarity are thought to be of *first importance.*

The phenomenon of capillarity—that of a column of liquid rising or being depressed by a small opening—is due to two causes (1) the surface tension of the liquid, and (2) the fact that the material of which the tube is composed has a greater or less adhesion for the liquid than the cohesion of the liquid itself.

Surface tension is the force at the surface of a liquid, which tends to make the liquid contract, and can be expressed by the following formula:

a) $$T = \frac{(pi) r^2 hqg}{2(pi) r \cos a},$$

where r equals the radius of the tube; h, the height of liquid standing in the tube; q, the density of the liquid; g, the acceleration of gravity; and a, the angle of contact between the liquid and the tube.

Surface tension is a linear function of the absolute temperature,[1] and that for water can be expressed by:

b) $$T = 0.21(370 - t)^2$$

where t equals the temperature Centigrade.

Pressure causes some change in surface tension, but presumably small. "For changes in the properties of water induced by pressure of, say 1,000 atmospheres are usually similar in magnitude and direction to those observed when a relatively small quantity of a salt is dissolved in it; and the surface tension of such dilute (0.5 N or less) solutions differs by only a small percentage from that of pure water."[3]

[1]Knipp, *Physical Review,* XI, 151.

[2]Johnston and Adams, *Journal of Geology,* XXII, 9.

[3]*Ibid.*

Different substances have different surface tensions, which can be calculated by means of formula a) with the necessary observed factors. For instance, crude oil at 20° C. has an average surface tension of about 25 dynes per cm.;[1] water at 18° C. about 75 dynes; and mercury at 20° C. about 540 dynes.[2]

Surface tension also varies with the nature of materials in surfacial contact. For instance, the surface tension of mercury when in contact with water is different from when in contact with air. Unfortunately, a number of such different values are not recorded, so that this discussion is limited to liquids in contact with air.

It is necessary that the adhesion of the material in the tube be either greater or less than the cohesion of the liquid, otherwise there would be no chance for surface tension to display itself. When adhesion is less than cohesion, depression in the liquid results, as in the case of the mercury and glass; when adhesion is greater than cohesion, there is a rise in the capillary tube. If adhesion greatly overbalances surface tension, the liquid surface may break and the liquid mount up the sides of the vessel, as in the case of some light oils in a low porcelain cup. Consequently, before one liquid will replace another in capillary openings the replacing liquid must not only have a greater surface tension but also a greater adhesive power for the material of which the tube is composed.

Capillary force according to equation a) is a function of surface tension, contact angle, diameter of pore space, density of liquid and acceleration of gravity. In the case of water-air surface the contact angle is 0, therefore ($\cos a$) equals 1; the density of water is 1; so the equation resolves itself into:

$$h=kT/r,$$

where k equals 0.00204.

Starting with a temperature of 15° C., at a depth of 100 m., the capillary pressures shown on p. 143 are computed from the above formula. Pressures are recorded in kilograms per square centimeter.

The following calculations show, first, that capillary pressures decrease with depth on account of the increase in tempera-

[1] Washburn, *A. I. M. E., L,* 831.

[2] Tait, *Properties of Matter,* p. 264.

ture; secondly, that above 750 m. capillary pressure in openings of 0.01 micron is greater than the combined rock and hydrostatic pressures; therefore capillarity is most important in the upper 3,000 ft. of the earth's crust; and thirdly, that above 5,000 ft. one liquid of greater surface tension and adhesion for the tube material should readily replace a weaker liquid in small openings; or in other words, the liquid of less surface tension should be concentrated in the larger openings.

CAPILLARY PRESSURE UNDER VARYING CONDITIONS*

Depth Meters†	Hydrostatic Pressure	Capillary Pressure For Pore Diameter of		Rock Pressure	Hydrostatic and Capillary Pressures
		100 Mc	0.01 Mc		
100	10	.03	306	27	316
500	50	.03	294	135	344
1,000	100	.027	278	270	378
2,000	200	.025	250	540	450

*Johnston and Adams, op. cit., XXII, 13.
†An increase of temperature of 1° for every 30 m. was used to obtain these results.

Capillary phenomena can take place in openings of 0.01 micron, as shown by Bakker,[1] where he concludes that the minimum size of capillary openings is a few times the diameter of the molecule. According to Whitney,[2] mud contains more than 10,000,000,000 particles per gram. If these were perfectly round particles, so that the pore space could be a maximum, the diameter of the individual would be about 3 microns. Therefore the maximum openings would be about 0.5 micron. Clay used in the following experiments was made up of particles which varied from 1 to 5 microns in diameter, as measured by a microscope. The openings then at a maximum would be a fraction of a micron. Now, since the openings in mud are evidently less than 1 micron by both of the above methods of approach, it has been assumed for the following hypothetical problem, that in compressed shales where the particles are not round nor of equal size the openings are diminished to 0.01 micron.

[1]*Zeitschrift fur physikalische Chemie,* LXXX, No 2, 129.

[2]*U. S. Dept, Ag., Weather Bureau, Bull.* 4., p. 73.

Capillary pressure of 300 atmospheres means that water will enter the pore spaces above static water level until the pressure in the pore tubes, due to the weight of the column of liquid above or otherwise, is equivalent to 300 atmospheres pressure; or that if the water is held back by a gas or liquid of less surface tension, it will accumulate a pressure in the said gas or liquid proportional to the difference in capillary pressures for that temperature and size of opening.

The following assumptions have been made for a hypothetical problem: (1) there exists a cavity or series of connected openings, larger than 0.5 mm., under a strip of rock 10,000 ft. wide and 1,000 ft. thick. The openings in the rock above are as small as 0.01 micron, and filled with water; (2) the material below the cavity is an oil shale in which the openings are 0.01 micron, and that water is in the lower part of this shale under sufficient head to make it rise to the level of the bottom of the cavity.

The water will drive the oil into the open cavity with a pressure equal to the difference in the capillary pressures of oil and water for that size opening. This amount for the given temperature of 15° C. and openings of 0.01 micron is approximately 200 atmospheres, or about 400,000 lb. per sq. ft. The weight of the rock column above is approximately 150,000 lb. per sq. ft.; and that of the full water column would be less than 62,000 lb., because the column cannot possibly act upon a full square foot, but only upon the area of pore space, for convenience say 50,000 lb. Now the resultant pressure upon the rock above the cavity is 400,000 minus (150,000 plus 50,000), or 200,000 lb. per sq. ft.

This pressure acts as upon a beam fixed at both ends. The capillary water above prevents the rising of the oil into the rock, but in turn affords no downward pressure on the oil in the opening, other than the weight of the hydrostatic column, as has been accounted for in the above assumptions.

The deflection for a beam fixed at both ends with a uniform load may be expressed by the following formula:

$$d=\frac{wl^4}{384EI},$$

where d is the deflection; w, the uniform load; l, length of beam; E, the modulus of elasticity; and I, the moment of inertia.

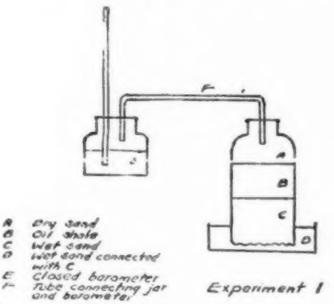
Substituting the values for a beam of rock 10,000 ft. wide, 1,000 ft. deep, 1 ft. broad, with E equal to 6,000,000 lb. per sq. in. (the value of granite), and I equal to $bh3/12$ or (1,000)3/12, the equation resolves itself into the following:

$$\frac{200{,}000\times 10{,}000\times 10{,}000\times 10{,}000\times 10{,}000\times 12}{384\times 6{,}000{,}000\times 144\times 1{,}000\times 1{,}000\times 1{,}000}$$

or approximately 72 ft. This means an anticline with a dip each way from the crest of about 1 degree.

Experiment 1.

Statement.—An open glass cylinder (3 in. in diameter, and 8 in. in length) was placed in a pan of wet sand, so that the sand filled the lower one-third of the cylinder. The water had free access from the sand in the pan to the sand in the cylinder. Then a layer of oil-saturated mud was placed in the cylinder upon the wet sand; this mud occupied about one-third of the cylinder and was above the level of the water in the pan. The cylinder was then filled with dry sand, and the top sealed with a tube attachment to a closed barometer. Readings of the mercury were taken before sealing and compared with a standard barometer in the same room.

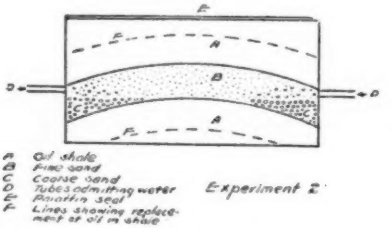


Results.—The water migrated upward about 1 cm. into the mud and the oil moved about the same amount into the dry sand. The mercury had risen within 24 hours, about 2½ cm. over the atmospheric pressure as compared with the barometer; it then remained stationary. The oil also migrated down into the wet sand and collected in some of the larger openings.

Experiment 2.

Statement.—A (¾-in.) layer of wet sand was placed between two layers of oil mud in a (8 in.×4 in.×4 in.) rectangular glass box. The sand layer was arranged in an arched manner so that the artificial anti-

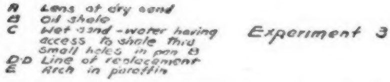
cline dipped about 30 degrees to either side. The sand grains in the top of the curve were small (all passing a 40-mesh sieve), while those in the troughs were comparatively coarse (none passing a 10-mesh sieve). The top was sealed with paraffin and water was allowed to enter the box through openings at the lowest horizon of the sand. This water level was never as high as the top of the curve in the sand.



Results—The water entered the mud in both directions from the sand layer and replaced about an inch strip of the oil in the mud. The oil moved into the coarser grains of sand and within 24 hours there was an oil pool in both synclines on either side of a water-filled anticline. Later, the oil began to move out of the openings which admitted water from the outside, and collected upon the surface of the water.

Experiment 3.

Statement.—A (3-in.) layer of oil mud was placed in a (round 14-in. diameter) pan, which had a number of small holes in the bottom. A circular lens of dry sand (3-in. in diameter and ½ in. thick) was fitted down in the center at the top of the mud. The surface was leveled as carefully as possible and covered with a ¼-in. layer of paraffin. This pan was then set in a pan of wet sand; so that the water level stood about 1 in. below the top of the mud in the first pan.



Results—After two weeks the paraffin had arched up over the dry sand, with a maximum rise of ⅜-in. The paraffin was punctured at this point, and within 24 hours the oil began to seep out and slowly run down the side of the dome. Several days later, seeps began to come out at various places, where the oil had dissolved its way through the paraffin. The oil also passed down out of the holes in the bottom of the pan through the sand, and collected upon the surface of the free water over the sand. Upon examination, the water had replaced amout 1½ in. of the oil in the bottom of the pan.

In the foregoing experiments, the mud was made from a mixture of dried clays, the particles of which measured from

0.005 to 0.001 mm., and Oklahoma crude oil (38 Baume). Enough oil was used to make the mud pack well.

Conclusions.

At the time of this reading only the results of the elementary experiments can be given. This paper does not attempt to say that capillary forces have ever caused anticlines in nature, but merely points out that possibility. At least one thing is borne out by the above experiments: that the segregation of oil and water in openings of the ordinary oil rocks is not according to the general hydrostatic idea, but that the water forces the oil into the larger openings regardless of elevation or structure. This does not do away with the general anticlinal theory of accumulation. On the contrary, it substantiates this theory, as the larger openings are more often in the crest of the anticline, regardless as to whether the oil caused the fold or whether the oil migrated there after the fold had been made.

SIGNIFICANT FEATURES OF WESTERN COAL DEPOSITS.

By CHARLES T. KIRK, *Albuquerque, New Mexico.*

(Tulsa meeting, February, 1917.)

The geology of western coal deposits has been regarded as less difficult than that of metallic deposits. With increasing demand for heat, power, and light, however, consideration now seems necessary for many minor features formerly overlooked, lest a commercial deposit be either undervalued or overvalued. Opportunities for investment may be overlooked where sufficient evidence, at least for prospecting, is manifest to one trained in the interpretation of features associated with workable western coal beds. Coal land locations, on the other hand, are not infrequently placed upon lands where promising features are really a misleading factor, especially as used by the ordinary type of promoter.

A considerable body of detailed principles helpful in the field study of western coals has been gathered by the geologists of the United States Geological Survey, but I know of no place where any great part of it is assembled for public reference. The work of that great body of survey men is perforce of so superficial and hurried a nature, I dare add, that their results do not measure up to the excellence of work done in the metals division of the Survey. The audience to which this paper is presented is one upon whose careful evaluations and prompt results more money is expended in a single year than in a decade upon the general and belated reports of the United States Geological Survey. You are well able to appreciate, then, any text that preaches for rapid and intensive study of an important economic problem.

To suggest in detail such principles as apply to the study of petroleum and natural gas in this presence would be like piping oil to Oklahoma. It seems better for me to take up the neighboring economic field of western coal deposits, and to submit a few loosely connected principles for their study.

By Western, I mean west of the one hundredth meridian line. And I so delimit the term not only for the reason usually mentioned—that the geologic age of the coal fields is generally different on the two sides of this line—but also because of climatic modifications, such as control of the height of water table and therefore the depth of oxidation.

The petroleum geologist readily appreciates the fact that a compact cap rock confines organic gases, and, as J. J. Stephenson, and later, M. R. Campbell, have pointed out, such a cover will prevent the escape of volatile products from a coal bed. In the case of our western lignites, however, field evidence shows that downward-moving oxygenated water will so volatilize this coal that it does not form anthracite as supposed by Stephenson, but well nigh all escapes as carbon monoxide or dioxide. The student of ores, therefore, sees a material difference between the oxidation of coal and of metallic deposits.

Geologic age, to be sure, cannot be disregarded by the careful student. Cretaceous and Tertiary coal is normally near the surface, and therefore subject to oxidation and erosion. If the dip slopes and their foot-hills be scanned closely, however, sizable deposits of near-surface beds will likely be found there somehow protected by their homoclinal roof better than are the flat-lying beds where water may soak downward for hundreds of feet. When coal occurs in these hogback structures it is relatively easily found along their upturned edges.

Closely connected with the reason for thin coal under inadequate cover is the pinching or thinning of the beds near the outcrop. And it is in this case that that field geologist who merely has time to trace the outcrop not infrequently overlooks the workable bed. The writer has followed down a prospector's slope, in the White Oaks (Capitan) district, New Mexico, and noted a thickening from 20 inches at the crop to 41 inches at 350 feet along the incline. Geologic evidence, as well as ash-content (see below) indicated that the crop was thin because of weathering. Again, in the Gallup district, New Mexico, he has noted such thickening, in this instance changing very suddenly from 22 inches up to 45 inches where a small fault (hutch, slip, jump-up) had off-set the beds and hindered circulation of oxidizing waters.

When the ash is unusually high for a given district in an apparently boneless sample either under pervious cover or near an outcrop, volitilization of carbon may be suspected.* When the bone will blast ("shoot") loose from the coal, or better, readily pick loose from it, the clean-looking coal was probably originally free from sediment; but if the bone adheres to the coal, it is a fair inference that the ash is partly sediment (now bone), grading into the coal, and not the residual silica, etc., of the original plant structure.

Cases of possible overvaluation are at hand, such as may be obviated by the close observance of simple geologic processes. In the region 20 miles northwest of Glendive, Montana, and again in the Snake River valley, Idaho, the author has observed what was evidently a thickened outcrop, caused either by hydration and swelling of the rather high ash or by slumping (creep) of the beds on a shale slope. In the Glendive locality he also found an occurrence of coal suspiciously free of beding planes and filled with crenulate structures almost like warped cross bedding. On extensive digging with a cavalry trenching tool, he found that this had been deposited in a small creek bed, the materials having been derived by the stream from its course across a few hundred feet of lignite several hundred feet up stream.

Among the characteristic tan to maroon deposits in the west many times bleached beds occur. From what has been said of the upward escape of carbon monoxide from organic bodies, does it not seem reasonable to expect organic material, perhaps a coal bed, under these bleached sediments? The light colored belt will naturally extend higher above the coal into sandstone or other porous material than into tight cover.

This bleached belt is usually the first to be tested by the layman for fire clay; whereas the geologist looks for fire clay below the coal where vegetation may have sapped out the potash, lime, and other fluxes, leaving mainly the alumina, silica, and other refractories. The thicker the coal bed the more refractory, and better the ganister or true fire clay. The finding of the coal and fire clay together obviously goes far toward increasing the value of both.

*See methods of United States Geological Survey and United States Bureau of Mines on field determination of ash.

The study of the overlying beds is also of great importance because of both geologic and mining significance. Clay roof is more unstable than sandstone; it will slack (hydrate) and become draw slate, cones, bells, etc., of the miners, and therefore induces dangerous rock falls, even where well timbered and lagged. A sandstone roof a foot thick, however, will usually bridge over a five-foot width of roadway without other support, and requires only occasional pillars in the rooms underground. While mining is usually safer and more economical under a sandstone roof, the continuity of the coal will run with better assurance under the clay or shale cover. This appears natural because the corrasive power of the sand-bearing agent is considerably greater than that of the gentle currents that lay down muds upon the peat beds.

Many cases of coal beds eroded under sandstone occur in the Mesaverde series in New Mexico. They are so common indeed as to render doubtful the establishment by one writer of an unconformity between Mesozoic and Cenozoic in the Madrid, New Mexico, field on the evidence that a three-foot coal bed is cut out for a few yards under a sandstone stratum. The fact that the whole bed has evidently been allowed to volatilize to a considerable extent under a cover greatly thinned by recent erosion makes the evidence for the "unconformity" seem even more doubtful.

In consideration of the uncertainties already mentioned, as well as the known variations from other causes, it is necessary to take observations as frequently as possible. Even the continuity alone of the bed, not to mention its changes in other respects, is untrustworthy between measurements a quarter of a mile apart. Reliable well logs, especially of a dug well, are of greater value as to thickness than is a weathered outcrop. Measurements along the constantly moist beds in the V of a valley or in a rincon, are more dependable than along sloping spurs, where alternating wet and dry conditions obtain, and rock creep usually distorts the thickness. When used with extreme caution, the rule of the United States Geological Survey that a workable bed may extend under the mesa for half a mile if the outcrop is a mile long, is fairly good. The fact that erosion channels and other lines of outcrop seldom bisect the original coal basin, however, makes the guide appear hazardous, if used without modification.

OIL AND GAS POSSIBILITIES IN MISSISSIPPI.

By A. F. Crider.

(Tulsa meeting, February, 1917.)

General Geology.

Mississippi lies within the area of the Gulf Coastal Plain. The surface rocks throughout the greater part of the state range in age from early Upper Cretaceous to Recent. The only exception to this is a small area in the extreme northeastern corner of the state where rocks of Pennsylvanian, Mississippian and Devonian age form the surface. These older rocks, base-leveled and submerged, form the sea floor on which the Cretaceous sediments were deposited with a marked nonconformity. Outside of the area where the older rocks come to the surface no deep wells have penetrated the older formations; so the principal source of oil or gas must be looked for in the Cretaceous and Tertiary formations.

The outcropping edges of the Cretaceous and Tertiary rocks in western Alabama extend approximately east and west, but in Mississippi they gradually change to a north and south direction, forming a semicircle with the convex side to the southwest. The normal dip of the rocks in Mississippi, therefore, will vary from due west in the northern part to due south in the eastern part.

Difficulties Attending Oil Investigations.

A number of difficulties are encountered by the geologist in the study of oil and gas possibilities in Mississippi. The chief of these are, (1) the lack of persistent horizons or key rocks on which to work out structures that may be present, (2) the overburden of loess and Lafayette sands and gravels which in places hide the stratified rocks, and (3) the physical nature of the surface, which in places makes general reconnaissance impossible and necessitates detailed work with plane table and

alidade. However, with a keen eye, a vivid imagination, and a capacity for hard work, most of these difficulties can be overcome.

Possible Source of Oil or Gas.

In the Caddo field of Louisiana there are three sands from which oil or gas have been obtained. These are the Nacatoch, the Blossom, and the Woodbine. The corresponding sands in the Mississippi nomenclature are the Ripley, the sandy member of the Selma Chalk, and the Tuscaloosa, respectively. These horizons in the region of Jackson, Mississippi, will be found approximatelly 1,300 feet deeper than the corresponding sands in the Caddo field.

In the region of Jackson, Mississippi, the normal dip is to the southwest. North of this the dip assumes a more westerly direction, while to the east of Jackson the dip is more to the south.

In northern Louisiana the normal dip is to the southeast. Between the two regions is a deep synclinal trough, the deepest part of which is west of the Mississippi River, perhaps as far west as the Ouachita River.

In northern Mississippi the collecting area for oil and gas will be to the deep synclinal trough to the west; in the region of Jackson it will be to the southwest and in the region east of Jackson it will be to the south.

The Most Favorable Parts of Mississippi Structures.

An interesting feature that deserves consideration in a study of Mississippi structures is the possible location of oil or gas on the structures.

In Oklahoma and Kansas the majority of the structures are found to be productive on the crest and for a distance down the long limb of the anticlines. In some instances oil is found down to the syncline on the short limb of the structures. The reverse is true in Louisiana. In Caddo, Crichton and most of the other Louisiana structures where oil has been found, the most productive parts of the structures are on the short limbs of the anticlines—on the opposite side from which the oil is supposed to have originated. In fact a large majority of the wells on the

long limbs of the structures have either been barren or small producers. If the short limbs of the structures are productive and the long limbs barren has the oil and gas originated from the long limb side? If the collecting area has been the short limb slope then the size of the wells is not controlled by the size of the collecting area for some of the largest wells of the country have been found on the short limb side of the Caddo field.

Just what part of the structures in Mississippi will be most productive, should oil or gas be present, cannot be determined without the drill. Since oil and gas must come from the same geologic horizons as in the Louisiana fields it is natural to conclude that the short limbs of the anticlines in Mississippi will be looked upon with most favor by geologists and oil companies.

Recent Developments in Mississippi.

What is perhaps the most important work done in Mississippi from the standpoint of the practical oil man is the drilling of the deep test two miles east of Vicksburg. This well, while barren of results as far as production is concerned, has given the geologist his bearing and has paved the way for future drilling in central Mississippi. The well was drilled to a depth of 3,462 feet and abandoned. A second well two miles north of the first well is now nearing completion. The first well was begun 132 feet above the top of the Vicksburg limestone and was stopped in the Eutaw formation, perhaps 250 feet above the top of the Tuscaloosa or Woodbine sand.

Future drilling in central Mississippi depended on the results of the first Vicksburg well. The local company who drilled the well before beginning the second well wanted to know whether or not the drill had penetrated the Selma Chalk. There was some doubt in the minds of the geologists who had kept in touch with the progress of the work as to just what formations had been penetrated. Some thought the Tertiary had not been penetrated, others thought the well was stopped far down in the Cretaceous. Fortunately, however, samples of drill cuttings had been saved and sent to the office of the state geologist at Jackson, where they were carefully studied by the writer and three other geologists and a log was prepared from the samples. While the divisions given to the various formations are perhaps not

just what they should be, owing to the inaccuracy in collecting samples from a rotary drill and the further difficulty in separating from drill cuttings the more or less heterogeneous mass of lower Tertiary formations, one thing is sure, viz: the top and bottom of the Selma Chalk have been clearly defined. The base of the Selma Chalk, in the Vicksburg well, was found at a depth of 3,270 feet. This puts the Woodbine sand of the Caddo field within reach of the drill in the region of Jackson, Mississippi. While the drilling there will be deep and expensive, the present price of the precious fluid and the nature of the structure make it an attractive proposition. If the structure proves good the chances are that it will be very good, and if it is bad—woe to the geologist who has recommended it.

Mr. Hopkins* has delineated the structure in the region of Jackson, Mississippi, extending the work as far west as the Mississippi River. While Mr. Hopkins' report has been helpful to the practical oil man there is much more information about the nature of the structure, especially its limitations, that should be known before testing the field with the drill. Elevations were taken by Mr. Hopkins on the middle member of the Vicksburg limestone. The absence of Vicksburg limestone north and northeast of Jackson makes it impossible to determine from this source whether or not the structure is really a doming anticline or merely a big "nose", as shown by Mr. Hopkins.

By taking the contact between the base of the Madison sand and the top of the Jackson clay or gumbo as the key rock for determining the elevations the nature and extent of the structure can easily be determined. The contact between the Madison sand and the Jackson clay is from 80 to 95 feet below the base of the Vicksburg limestone. This gives a decided advantage in working out the structure north and northeast of Jackson where the Vickburg limestone would be 80 to 95 feet in the air.

*Bulletin 541 D, U. S. Geological Survey.

OIL DEVELOPMENT IN COLOMBIA, SOUTH AMERICA.

By K. D. White, *Tulsa, Oklahoma*

(Tulsa meeting, February, 1917.)

As considerable interest is centering in the petroleum possibilities of Tropical America, and as the greatest activity is now in Colombia, it seemed to me worth while to give a brief description of the possible petroleum lands of that country.

In Colombia manifestations of petroleum, as they are called, are so common as to be the rule rather than the exception. Mud volcanoes, gas springs, saline and sulphur water springs, seepages, or springs of petroleum varying from liquid asphalt without even the odor of petroleum, to oils that are practically composed of kerosene and gasoline, are of widespread occurrence. Veins of gilsonite, grahamite, and probably other allied mineral hydrocarbons are present in several localities to a considerable extent, but do not have the wide distribution of the lighter members of the hydrocarbon series.

In the latter part of the eighteenth century, while this country was yet a Spanish province, Baron von Humboldt visited it and called the world's attention to these manifestations. He described at length the mud volcanoes at Turbaco, a short distance from Cartagena, and called them Turbacos from the type locality. Production on a commercial scale was not really attempted until the Standard Oil Company acquired properties in the valley of the Sinu River, and began operations in 1914. Prior to this time, desultory attempts were made in the vicinity of Cartagena and Barranquilla to the extent of drilling a dozen or so wells without success by Colombian, Canadian, British and some American capital. Also in 1912 and 1913 English interests attempted to secure the petroleum rights on government lands, along with other privileges, such as wharfing and railroad concessions. Some competition then arose from certain American interests and the concessions were not granted.

The Standard Oil Company drilled three wells each about 2,200 feet deep, without success, finding only showings of oil and a little gas. This was considered an adequate test and the company abandoned the project, returning the properties to the owners in the summer of 1916.

The present interest really started when a company of Pittsburg capitalists in the spring of 1916 chartered a yacht, invited a number of Pittsburg citizens to be their guests and sailed for Colombia, to examine a concession they had acquired on a large acreage of government land in the Magdalena valley. They arrived in due time at Cartagena, crossed over the mainland and chartered a steamboat for passage up the Magdalena River.

This expedition gave the country considerable advertising, and the stimulating influence of the rising price of oil caused a number of American companies to send representatives there to acquire holdings. During the fall of 1916 at least half a dozen prominent American companies had agents in that country trying to acquire acreage, and more are going in every month.

Colombia may be divided into seven provinces, which are more or less geographic units. Each province has a distinct character of petroliferous evidence, structural deformation and a distinct stratigraphic section. The seven provinces are:

(1) The Coastal region extending from the Gulf of Darien to the mouth of the Magdalena River, including the Sinu River valley and the lower part of the Magdalena River valley.

(2) The Santa Marta Mountain range and the Goajira Peninsula.

(3) The lower Magdalena River valley below the falls at Honda.

(4) The Upper Magdalena River valley.

(5) The Meta River valley, the eastern slope of the Andes in the Orinoco River drainage basin.

(6) The Lake Maracaibo drainage basin.

(7) The Pacific Coast region.

Each province has its separate engineering and production problems, but time will not permit going into these.

I. In the Coastal region, the petroliferous evidences are mud volcanoes, some covering acres in extent, gas springs, salt water springs, seepages of petroleum varying from heavy asphaltic oils with a gravity as low as 10° Baume, through amber oils composed almost entirely of the lubricants to white oils that are practically pure kerosene and gasoline. The seepages are in general either in the shattered zones of faults of considerable displacement, or in the crushed core of closely folded assymmetrical anticlines. The surface rocks are either Miocene or Pliocene sediments. The Miocene of the coast has a thickness of at least 8,000 feet.

II. Of the Goajira Peninsula and the Santa Marta Mountain Ranges, I have no personal knowledge, nor is published data available.

III. The valley of the Lower Magdalena River extending from 200 to 500 miles from the coast is a region that is very unhealthful and difficult to travel. The valley which is bounded by the Eastern and Central Andean Ranges is in places, 100 miles wide. It is in this area that the principal oil activity is now centering.

The petroleum evidence is in the form of seepages varying from liquid asphaltum to amber oils, gas springs, sulphur water springs, veins of gilsonite and grahamite, and asphaltum impregnated sandstones. The majority of the oil seepages are of thick black asphaltic oil of a gravity of about 12° to 14° Baume. The larger number of seepages are from black carbonaceous limestones and shales of Cretaceous age, though asphaltic sandtsones, gilsonite and grahamite veins and oil seepages occur in beds of latter age.

The structure is of the block fault mountain type. This major structure has been complicated by intense folding, which is parallel to the Andean ranges and less intense transverse or cross folding. The lands that may be studied where the petroleum horizons may be reached by the drill, are confined to a narrow belt at the foot of the two mountain ranges.

IV. The Upper Magdalena valley is much narrower than the lower and can be studied across its entire width, though the structure of the older rocks is masked by a thick covering of late Tertiary volcanic tuffs, or pyroclastics.

Petroleum evidence consists of seepages of thick black asphaltic oils, gravity 14° Baume, and amber oils gravity 18° Baume. They are in general found along the lines of faulting, where the black, carbonaceous limestones and shales of Cretaceous age have been brought to or very close to the surface. Seepages do occur in rocks of later age, especially the Tertiary tuffs, but the oils are undoubtedly migratory.

The structure is of the block fault mountain type. In the mountain blocks, the upward movement or upthrow is on the east and the downthrow is on the west.

V. Very little is known of the Meta River valley on the eastern slope of the Andes. Large petroleum springs are reported, especially on the plains of San Martin. Sir Boverton Redwood makes note of them, and his comments check very closely the reports that came to me in Colombia.

VI. In the Lake Maracaibo drainage basin, in the Department of Santander, numerous seepages of high grade oil are coming from the crest of an asymmetrical anticline. The seepage oil has been collected in pits and refined for local consumption.

VII. The Pacific Coast region has, according to Ralph Arnold, hot and saline water springs which emit gas, and some seepages of heavy oil. The predominant rocks are shales probably of mid-Tertiary age, that have been sharply folded.

In closing, I might call attention to the fact that petroleum in commercial quantities has not been found up to the present time in Colombia, but that the country contains a large acreage of land that appears to have excellent possibilities.